PROCEEDINGS

Near-Term Objectives Workshop

Open Architecture Control for Robotics

June 28, 2000
Marriott Eagle Crest Conference Resort
Ypsilanti, Michigan

A Workshop Sponsored by

Robotic Industries Association
900 Victors Way, P.O. Box 3724
Ann Arbor, MI 48106
www.robotics.org

National Institute of Standards and Technology
100 Bureau Drive, Stop 8230
Gaithersburg, MD 20899-8230
www.isd.mel.nist.gov

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Executive Summary

The Near-Term Objectives Workshop on Open Architecture Control for Robotics was a one-day workshop help at the Marriott Eagle Crest conference center in Ypsilanti, Michigan on June 28, 2000. The workshop stemmed from a discussion of "first wave" guidelines for interfacing to factory networks that were presented at the Open Architecture Controls for the Robotics Industry Workshop, held in Orlando in February 2000. These include ethernet (copper CAT 5/6 and fiber optic media); TCP/IP networking protocols; SNMP network management; NTP time synchronization; and XML and Internet browsers for data representation and presentation.

The workshop consisted of seven presentations from both the end user and vendor communities, followed by a discussion period during which the attendees broke up into three parallel groups to discuss the topics and determine a course of action for the near future. The breakout session results can be found in the proceedings.

Two concepts focused the discussions. The "PC-augmented" architecture was described by some of the attendees at the 2000 International Conference on Robotics and Automation. This is a split of the robot controller into a proprietary part and an open (typically PC-based) part. This division allows vendors to achieve safe and reliable systems while allowing users a practical degree of openness via standard interfaces on the open side. The second concept was a division of the external interfaces of a robot controller into three areas: factory data integration, peripheral integration, and graphical display. The first-wave guidelines relate to the first of these areas. Factory data integration, for a PC-augmented architecture, thus became the subject of this workshop.

The overall action plan for this group is as follows:

1. Gather potential first-wave standards (subject of this workshop).
2. Collect field experiences with first-wave standards.
3. Prioritize standards based on potential benefit and ease of implementation.
4. Develop implementation and integration test plans for prioritized standards.
5. Launch testing.

The following interim actions resulted from this workshop:

1. Presenters and selected others were asked to report on so-called "war stories" of experiences with any of the proposed first-wave guidelines. Specific assignments can be found in the Action Items section of the proceedings.
2. NIST was asked to draft a questionnaire soliciting case studies of field experiences to supplement those from (1).
3. All the attendees were asked for proposals on how to conduct follow-on work using remote collaboration tools.
4. The group will use the email list, openarch@nist.gov, to submit their reports and to participate in ensuing discussions that will prioritize interoperability tests for selected high-value protocols.

The next meeting is tentatively scheduled for the day prior to the RIA Forum in Orlando in November.

Near-Term Objectives Workshop
Attendees List

Mr. Dennis Archer
Systems Development Engineer
DaimlerChrysler Corporation
800 Chrysler Drive/CIMS: 482-05-08
Auburn Hills, MI 48326-2757
Phone: (248) 576-6174
Fax: (248) 576-2150

Mr. Craig Battles
Tech. Fellow - Robotics
Boeing Commercial Airplane Group
P.O. Box 3707, M/C 97-18
Seattle, WA 98124-2207
Phone: (425) 234-0494
Fax: (425) 237-1465

Mr. Ron Behar
Software Engineer
Kawasaki Robotics
28059 Center Oaks Court
Wixom, MI 48393
Phone: (248) 305-7610
Fax: (248) 305-7618

Mr. Sushil Birla
Engineering Group Manager
General Motors
30300 Mound Road
MC 480-109-164
Warren, MI 48090-9040
Phone: (810) 602-9834
Fax: (810) 947-0910

Mr. Jeff Bonvallet
Vice President
MEKAnize Robots
975 Elkton Drive
Colorado Springs, CO 80907
Phone: (719) 598-3555
Fax: (719) 548-9227

Mr. George Brancato
Applications Engineer
Ellison Robotics Midwest
4630 Weaver Parkway
Warrenville, IL 60555-3928
Phone: (630) 393-8900
Fax: (630) 393-6080

Mr. Bruce Casner
Sr. Staff Engineer
Miller Electric Mfg. Co.
1635 West Spencer Street
P.O. Box 1079
Appleton, WI 54912-1079
Phone: (920) 735-4191
Fax: (920) 735-4003

Mr. Nick Dimitrov
VP of Software Development
Radix Controls
2105 Fasan
Oldcastle, ON N0R 1L0
Canada
Phone: (519) 737-1012
Fax: (519) 737-1810

Mr. Claude F. Dinsmoor
Mgr Controller Software Development
FANUC Robotics North America, Inc.
3900 W. Hamlin Road
Rochester Hills, MI 48309-3253
Phone: (248) 377-7174
Fax: (248) 377-7477

Mr. John M. Evans
Chief, Intelligent Systems Division
NIST
100 Bureau Drive, Mail Stop 8230
Gaithersburg, MD 20899
Phone: (301) 975-3418
Fax: (301) 990-9688

Mr. David P. Faulkner
Executive Vice President of Marketing
Cimetrix
6979 South High Tech Drive
Salt Lake City, UT 84047
Phone: (801) 256-6500
Fax: (801) 256-6510

Mr. Jeff Fryman
Manager, Standards Development
Robotic Industries Association
P.O. Box 3724
900 Victors Way, Suite 140
Ann Arbor, MI 48106
Phone: (734) 994-6088
Fax: (734) 994-3338

Mr. David Gravel
Sr. Technical Specialist
Ford Motor Company, AMTD
24500 Glendale Ave.
Redford, MI 48239
Phone: (313) 592-2743
Fax: (313) 592-2212

Harley Hammond
Senior Engineer
Applied Manufacturing Technologies
1200 Harmon Road
Auburn Hills, MI 48326-1550
Phone: (248) 391-9532
Fax: (248) 391-5882

Mr. Andrew G. Hamor
Staff Project Engineer
General Motors Corporation
Robotic Engineering
30300 Mound Road/480-109-163
Warren, MI 48090-9040
Phone: (810) 602-9957
Fax: (810) 947-1039

Mr. James Heaton
President
KVQuest Ltd.
P.O. Box 550
Chelsea, MI 48118
Phone: (734) 475-9400
Fax: (734) 475-5752

Mr. Dan Hornbeck
Sr. Area Manager - PLC/HMI
Rockwell Automation
1849 West Maple Road
Troy, MI 48084
Phone: (248) 280-7023
Fax: (248) 280-0611

Mr. Tony Hummel
Principle Engineer
Nachi Robotics Advanced Technology
23370 Commerce Drive
Farmington Hills, MI 48335
Phone: (248) 473-7537
Fax: (248) 473-7597

Mr. Shinji Kato
Software Coordinator
Nachi Robotics Advanced Technology
23370 Commerce Drive
Farmington Hills, MI 48335
Phone: (248) 473-7537
Fax: (248) 473-7597

Mr. Volker Knack
Manager, Software and Controls
Adept Technology, Inc.
150 Rose Orchard Way
San Jose, CA 95134
Phone: (408) 434-6220
Fax: (408) 434-5119

Mr. William Kneifel
Development Manager
Trellis Software & Controls
2619 Product Drive, Suite 106
Rochester Hills, MI 48309
Phone: (248) 844-0560
Fax: (248) 853-0707

Mr. John Lapham
Engineering Manager
Robotic Workspace Technologies, Inc.
17105 San Carlos Boulevard, Suite A6151
Fort Myers Beach, FL 33931-5336
Phone: (941) 466-0488
Fax: (941) 466-7270

Mr. Rob LaRose
Engineer
Lincoln Electric
22801 St. Clair Avenue
Euclid, OH 44117
Phone: (216) 383-2635
Fax: (216) 383-8382

Mr. Doug Miller
CTO
IRobotics
3036 Madan Park Drive
Indianapolis, IN 46241
Phone: (317) 244-7626
Fax: (317) 244-8650

Mr. James T. Olejniczak
Electrical Engineer
Miller Electric Manufacturing Co.
1635 West Spencer Street
P.O. Box 1079
Appleton, WI 54912-1079
Phone: (920) 735-4498
Fax: (920) 735-4041

Mr. Fred Proctor
Group Leader, Control Systems Group
NIST
100 Bureau Drive
Mail Stop 8230
Gaithersburg, MD 20899
Phone: (301) 975-3425

Mr. Ross Rawlings
President & CEO
Radix Controls Inc.
2105 Fasan Drive
Oldcastle, ON N0R 1L0
Canada
Phone: (877) 467-2349
Fax: (519) 737-1810

Mr. Gary J. Rutledge
VP, Advanced Product Development
FANUC Robotics North America, Inc.
3900 W. Hamlin Road
Rochester Hills, MI 48309-3253
Phone: (248) 377-7141
Fax: (248) 276-4041

Mr. Todd Scott
Software Engineer
Nachi Robotics Advanced Technology
23370 Commerce Drive
Farmington Hills, MI 48335
Phone: (248) 473-7537
Fax: (248) 473-7597

Mr. Craig Snyder
Systems Group Leader
Applied Manufacturing Technologies, Inc.
1200 Harmon Road
Auburn Hills, MI 48326-1550
Phone: (248) 391-9527
Fax: (248) 391-5882

Mr. Martin A. Stembel
Software Engineer
IRobotics
3036 Madan Park Drive
Indianapolis, IN 46241
Phone: (317) 244-7626
Fax: (317) 244-8650

Mr. Dave Sytkowski
Tower Automotive
3533 North 27th Street
Milwaukee, WI 53216
Phone: (414) 447-4351
Fax: (414) 447-4882

Mr. Carl Traynor
Vice President, Business Development
Dynalog, Inc.
6001 N. Adams Road, Suite 125
Bloomfield Hills, MI 48304
Phone: (248) 203-9602
Fax: (248) 203-9605

Mr. Clifton N.B. Triplett
Global Produce Product Information Officer
General Motors Corporation
200 Renaissance Center
Mail Code 482-B34-B45
Detroit, MI 48265-2000
Phone: (313) 667-4905
Fax: (313) 667-4678

Mr. Donald A. Vincent
Executive Vice President
Robotic Industries Association
900 Victors Way, Ste. 140
P.O. Box 3724
Ann Arbor, MI 48106
Phone: (734) 994-6088
Fax: (734) 994-3338

Ms. Becky Walter
Customer Key Accounts - Engineering Leader
KUKA Robotics Corporation
6600 Center Drive
Sterling Heights, MI 48312
Phone: (810) 795-4294
Fax: (810) 795-4871

Mr. Sean Walters
Project Manager
Panasonic Factory Automation Co.
9377 W. Grand Avenue
Franklin Park, IL 60131
Phone: (847) 288-4343
Fax: (847) 288-4564

Mr. Mitchel R. Ward
President
Trellis Software & Controls
2619 Product Drive, Suite 106
Rochester Hills, MI 48309
Phone: (248) 844-0596
Fax: (248) 853-0518

Mr. Gregory Webb
Manager Software R&D
Motoman Inc.
1050 South Dorset Road
Troy, OH 45373-4708
Phone: 937-440-2621
Fax: 937-440-2626

Mr. Walter K. Weisel
President & CEO
Robotic Workspace Technologies, Inc.
17105 San Carlos Boulevard, Suite A6151
Fort Myers Beach, FL 33931-5336
Phone: (941) 466-0488
Fax: (941) 466-7270

Mr. James W. Wells
Principal Engineer - Robotics
General Motors Corporation
Controls, Robotics & Welding
30300 Mound Road/480-106-163
Warren, MI 48090-9040
Phone: (810) 602-9879
Fax: (810) 947-1039

Mr. Marc Whitley
Intern
General Motors
200 Renaissance Center
Mail Code 482-B34-B45
Detroit, MI 48265-2000
Phone: (313) 665-5172

Mr. Gary Workman
Staff Development Engineer
General Motors
30300 Mound Road
M/C 480-109-267
Warren, MI 48090-9040
Phone: (810) 602-9918

Mr. Brian Zielinski
Intern
Tower Automotive
3533 North 27th Street
Milwaukee, WI 53216
Phone: (414) 447-4351
Fax: (414) 447-4882

Near-Term Objectives Workshop
Open Architecture Control for Robotics

Wednesday, June 28, 2000
Marriott Eagle Crest Conference Resort
Ypsilanti, Michigan

Sponsored by
Robotic Industries Association
National Institute of Standards and Technology

Agenda

7:30 am	Registration
8:30 am	Welcome, Meeting Objectives, and Architectural Framework Fred Proctor and John Evans, NIST
8:45 am	Performance of Ethernet for Control Gary Workman, General Motors Corporation
9:15 am	Ethernet for the Factory Floor Dan Hornbeck, Rockwell Automation
9:45 am	Open Architecture: Where should we spend our effort? Bill Kneifel, Trellis Software & Controls
10:15 am	Break
10:30 am	Open Architecture Interfaces to Robot Controllers Gary Rutledge, Fanuc Robotics
11:00 am	Application of OPC XML to Robotics Sushil Birla, General Motors Corporation
11:30 am	Extensibility Issues for Open Architecture Controllers Dave Gravel, Ford Motor Company Clif Triplett, General Motors
12:00 noon	Lunch
1:00 pm	Breakout Discussions
2:45 pm	Break
3:00 pm	Wrap-up, Action Items, Next Steps
4:30 pm	Adjourn

Near-Term Objectives Workshop

Section One

Introduction

Presented by:

Fred Proctor
Group Leader
Intelligent Systems Division
National Institute of Standards and Technology


Near-Term Objectives Workshop
Open Architecture Control
for Robotics
June 28, 2000
Ypsilanti, Michigan

Near-Term Objectives Workshop

- Follow-up to February 2000 Open Architecture workshop in Orlando
- Those proceedings are on the open architecture web page:

  `www.isd.mel.nist.gov/projects/openarch`
- Scope of this workshop: “First Wave” objectives
  - networking: Ethernet, TCP/IP, fiber optic
  - network management: SNMP
  - time synchronization: NTP
  - data representation: HTML, XML

Meeting Objectives

- Understanding of the current state of robotics market with respect to Wave 1
- Agreement on what needs to be accomplished in the near term
- Commitment from vendors and users to engage in validation tests
- Work breakdown and schedule

Other Issues

- RIA's open architecture chat highlighted two important areas
  - Ethernet at the "top," a focus of this workshop
  - Real-time Ethernet as a device network
- ICRA discussions in San Francisco described "PC augmented" architecture
- MAA plan for interoperability of metrology equipment and software

Near-Term Objectives Workshop

Section Two

Open Architecture in Metrology Automation

Presented by:

John Evans
Chief
Intelligent Systems Division
National Institute of Standards and Technology

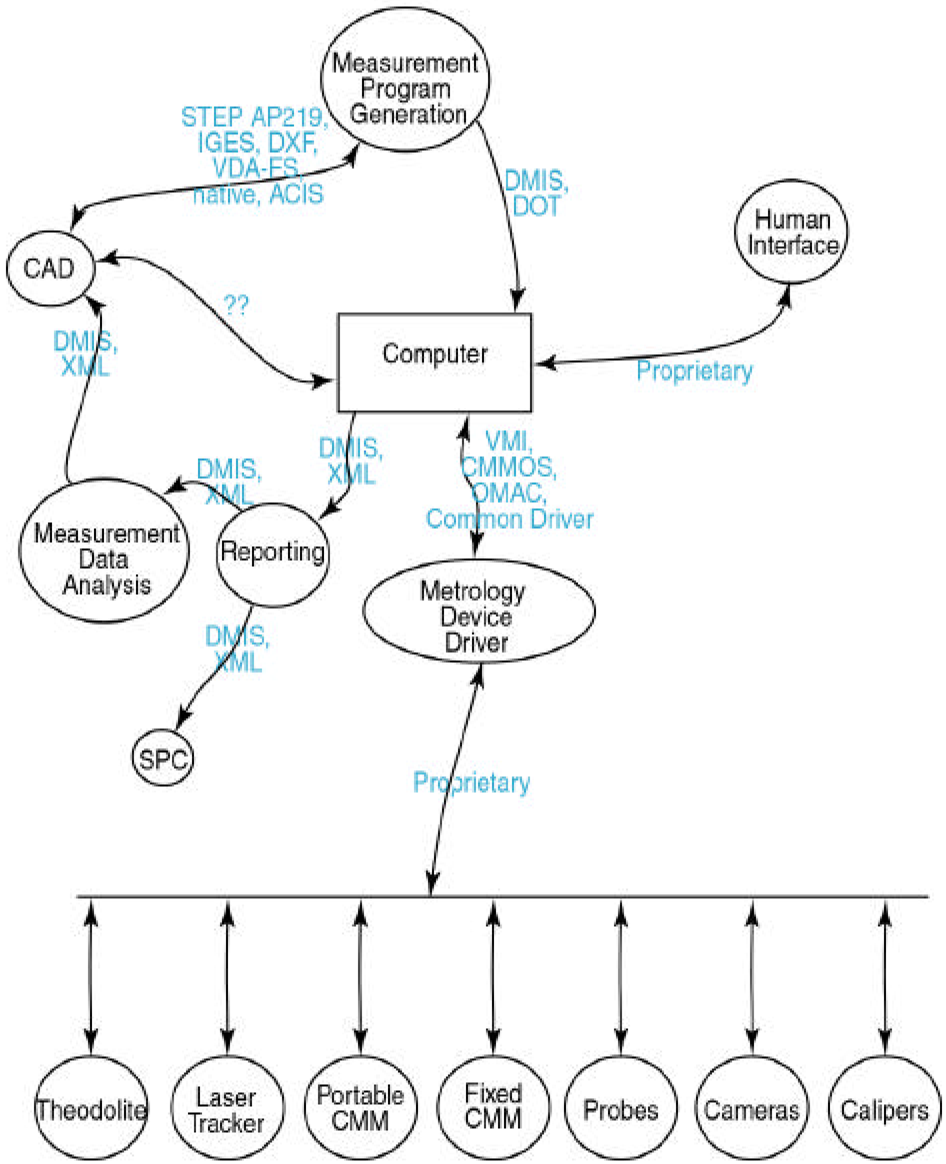
Open Architecture
in
Metrology Automation

A Workshop
Cosponsored by

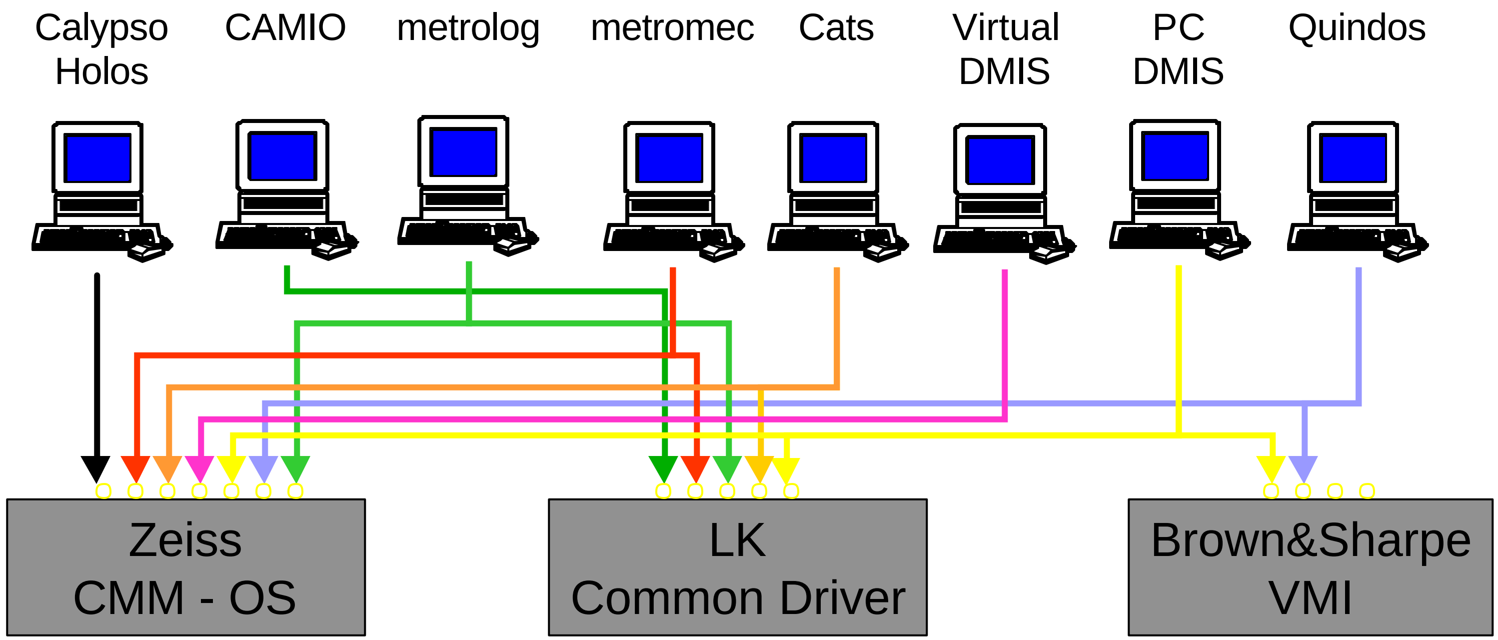
Metrology Automation Association
National Institute of Standards and Technology

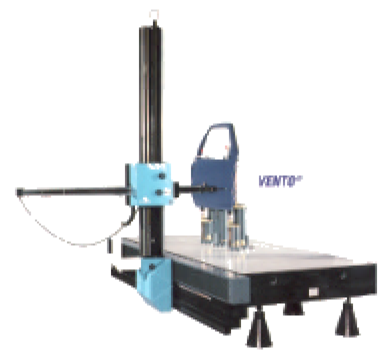
May 2-3, 2000
NIST, Gaithersburg, MD

Metrology System Common Modules and Interfaces

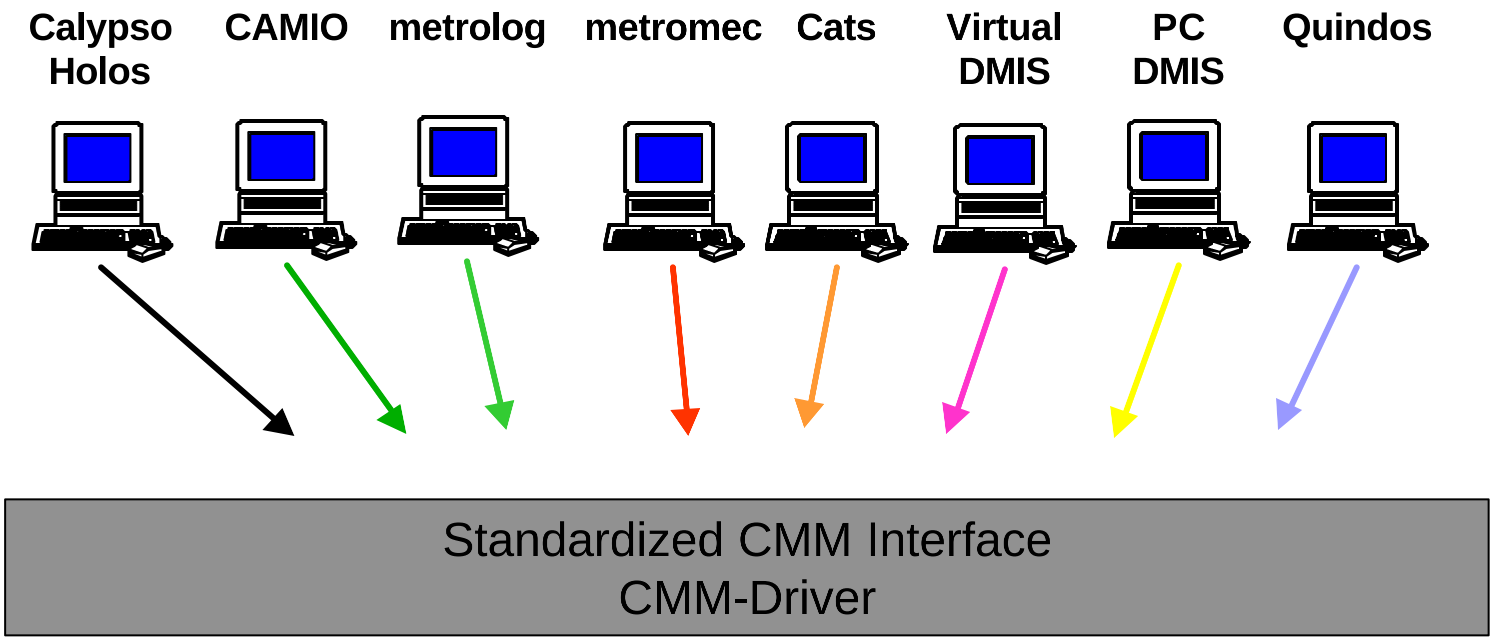


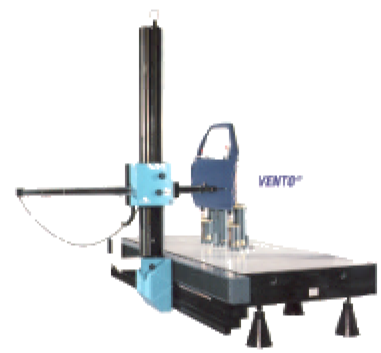
Inspection Machine Control
Current Situation





Common DME Interface





Near-Term Objectives Workshop

Section Three

Real-Time Control Level Ethernet

Presented by:

Gary Workman
Staff Development Engineer
General Motors

Real-Time Control Level Ethernet

June 28, 2000
RIA Open Architecture Workshop

Gary C. Workman
General Motors North America
Controls Robotics & Welding
E-mail: Gary.C.Workman@GM.COM

Overview

- Introduction / Background
- Ethernet Evolution
- Control Level Ethernet vs I/O Level Ethernet
- Control Level Ethernet Performance Studies
- Control Level Ethernet Interface Issues
- Plans / Summary

Different Network Levels Have Different Requirements

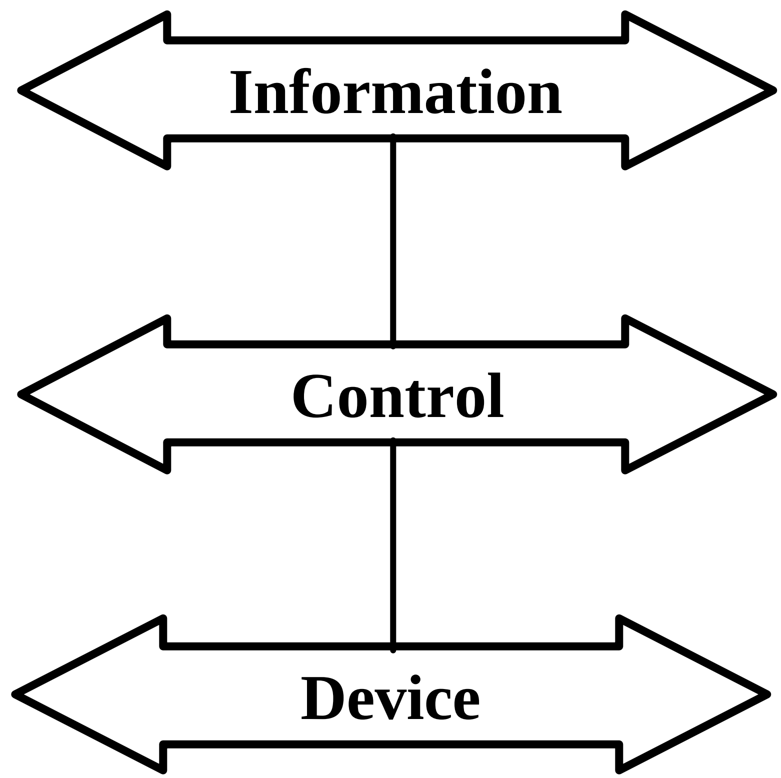
	Primary Use	Network Size	Data Volume	Response Time	Cost
Information	Plantwide Information	Large *	High *	Moderate	High / Moderate
Control	Peer-to-Peer Remote I/O	Moderate	Moderate	Very Fast *	Moderate
Device	Wire Replacer	Small	Low	Fast	Very Low *

* **indicates primary requirement**

Ethernet

ControlNet

DeviceNet



Background

- Target Application: PLC Peer to Peer Interlocking of Body Shop Tooling
- Target Performance: Comparable to Existing, Proprietary Control Level Networks

- Goal: Two Network Technology Open Communication Architecture
- Benefits: Improved Information Exchange Between Information Systems and Control Systems, Indirect Cost Savings

What Does It Cost To Support A Network Technology?

- Network Support Tools
  - Design Tools
  - Installation Tools
  - Configuration Tools
  - Monitoring Tools
  - Management Tools
  - Diagnostic Tools
- Associated Personnel Training Costs
- Additional Spare Parts Inventories

Ethernet Evolution

"Today's Ethernet has about as much resemblance to 1980s Ethernet as today's personal computers have to computers of that era."

"… don't dismiss Ethernet as being viable on the plant floor based on dated perceptions and information."

Control Engineering article - June, 1999

In other words: It's not your father's Ethernet

Real-Time Ethernet
Network Infrastructure Direction

- Full Duplex Switched Ethernet
  - Eliminates collision delays
  - Insignificant switching delays
  - Low cost bandwidth insurance
  - easy to troubleshoot (noise and congestion) problems

Assumptions: Most real-time communication is between devices connected to the same switch. Switch management techniques will be available to filter broadcast traffic.

Ethernet as a Real-Time Network: Why Ethernet ?

- Low cost, widely available hardware
- Internationally standardized
- Readily available expertise
- High speed, high bandwidth network
- Continuously evolving technology

Ethernet as a Control Level Network: Issues

- Non-Deterministic Performance
- Active Media
- Office Grade Components
- Operation in Electrically Harsh Environments
- Network Topology
- Lack of Redundancy
- Ability to Handle Both Control and MIS Information
- Lack of a Common Application Layer Protocol

Ethernet As An I/O Level Network
Additional Issues

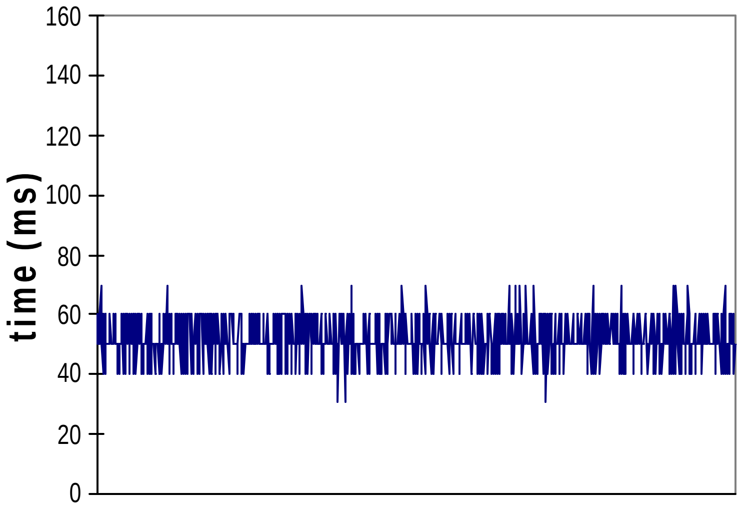
- Wiring topology
- Industrially hardened interface
- Power on the wire
- (Redundancy)
- Cost

Assumption: An ethernet network supporting real-time I/O will be exclusively dedicated to that task

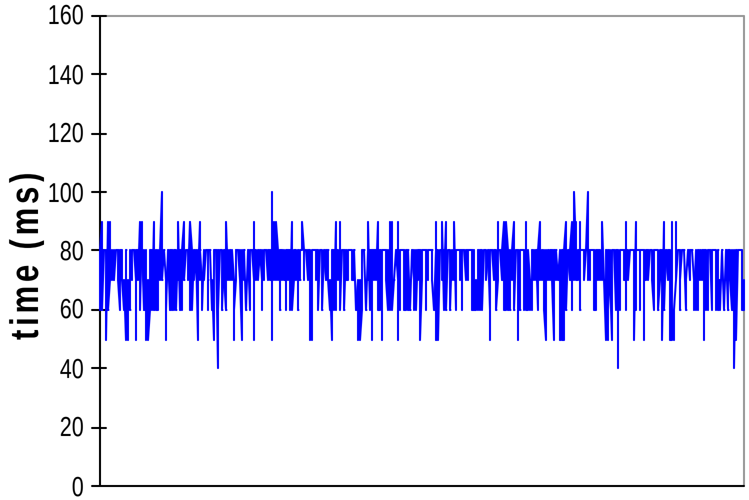
Ethernet Performance Studies

- PLC-5 Ethernet Vs Remote I/O Performance Study
  - 1997 Laboratory Study Showed that Ethernet Performance is Comparable to Remote I/O Performance
- (Powertrain) Ethernet Interlocking of PC-based Controllers Performance Studies
- SLC-505 Ethernet Vs Remote I/O Performance Study
- Contracted Ethernet Performance Study With University of Michigan
  - Prioritization of Real-Time Traffic Combined With Non-Real-Time Traffic Smoothing

PLC-5 Test Results



Ethernet Messaging Times



RIO Messaging Times

Control Level Ethernet Interface Issues

One key conclusion I have drawn from our Ethernet performance studies and investigations is:

The Ethernet network interface specific to a device, not the Ethernet network infrastructure, is the most significant performance bottleneck to real-time Ethernet communications.

Control Level Ethernet Interface Issues

- Ethernet message priority
- Real-time message responsiveness
- Real-time communication resources
- Application program interfaces
- Common application protocol

Assumption: For cost reasons, real-time and non-real-time traffic will share a single ethernet interface.

Ethernet Message Priority

- Interface implemented behavior Vs. protocol required behavior
- At a minimum, two levels of traffic priority must be supported (real-time traffic and non-real-time traffic).
- For outgoing traffic: All real-time messages should be sent before any non-real-time messages are sent.

Assumption: Sufficient resources exist to process all incoming traffic in the order it is received.

Real-time Message Responsiveness

- TCP (Transmission Control Protocol) error recovery behavior is inappropriate for many real-times message exchanges. It introduces “intolerable” delays.
- UDP (User Datagram Protocol) is simpler and faster. It allows for broadcast messages. Applications that use UDP must implement their own error recovery.

Assumption: Benefits of using TCP/UDP/IP protocols outweigh the costs of implementing them.

Real-time Communication Resources

- How many communication associations can be supported ?
- How many ethernet messages can be generated / consumed in a single program scan ?
- How fast can messages be processed ?

Assumption: The control program application execution environment has control of the ethernet interface driver.

Application Program Interfaces

- What modes of interaction (e.g. polled, cyclic, change of state) are supported ?
- What types of communication relationships (e.g. connection oriented, uni-cast, broadcast) are supported ?
- Can communication associations be dynamically modified ? How much pre-use configuration is required ?
- How is an application program informed of communication faults ?

Common Application Protocol

- MMS (EPRI)
- OPC (OPC Foundation)
- HSE (Fieldbus Foundation)
- Modbus/TCP (Schneider)
- CIP (ControlNet International)
- EGD (General Electric)
- Profibus over Ethernet ?
- IEEE 1451(Hewlett Packard)

Current Plans - Phase I

- Use Ethernet/IP for Body Shop Tooling Controls
  - Beta Test ControlNet over Ethernet Performance in the Validation Lab (Q2/00)
  - Pilot ControlNet over Ethernet on Underbody Line at MFD Pontiac (Q4/00 - Q2/01)
    - PLC to PLC communication
    - PLC to HMI communication
  - Inform CRW Organization (and Suppliers) of Potential Network Architecture Change.

Current Plans - Phase II

- Expand Scope of Real-Time Ethernet to Include Additional Devices and Services.
  - Robot Controllers, Weld Controllers, RF Tag Readers, Perceptron Inspection Systems
  - Multicast, Explicit Priority,Change-of-State Behaviors

Summary

- GM Is Actively Investigating a Full Duplex Switched Ethernet Infrastructure to Support Real-Time, Control Level Ethernet Communications.
- GMNA Is Participating in ControlNet International's Ethernet/IP Efforts.
- Rockwell Automation Is a Key Partner in CRW's Control Level Ethernet Efforts. The Control Logix Platform Will Be an Integral Part of Future Performance Testing and Production Pilot Installations.

Near-Term Objectives Workshop

Section Four

EtherNet IP: An Open Standard for Real-time Control Over Ethernet

Presented by:

Dan Hornbeck
Sr. Area Manager - PLC/HMI
Rockwell Automation

Robotic Industries Association

EtherNet/IP

An Open Standard for Real-Time Control Over Ethernet

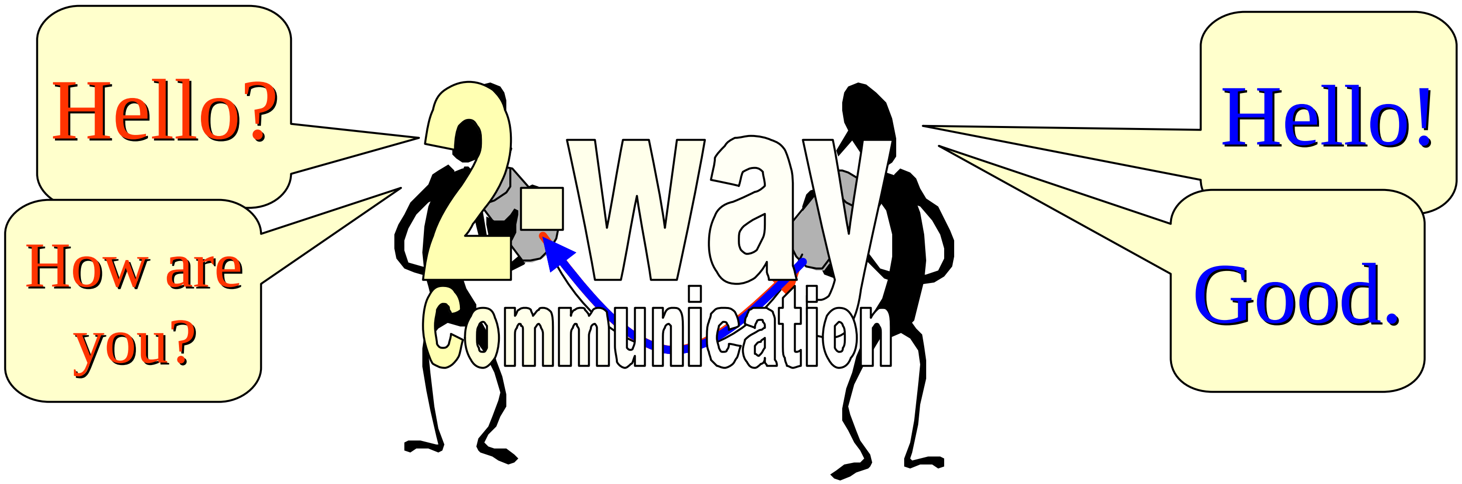
Dan Hornbeck

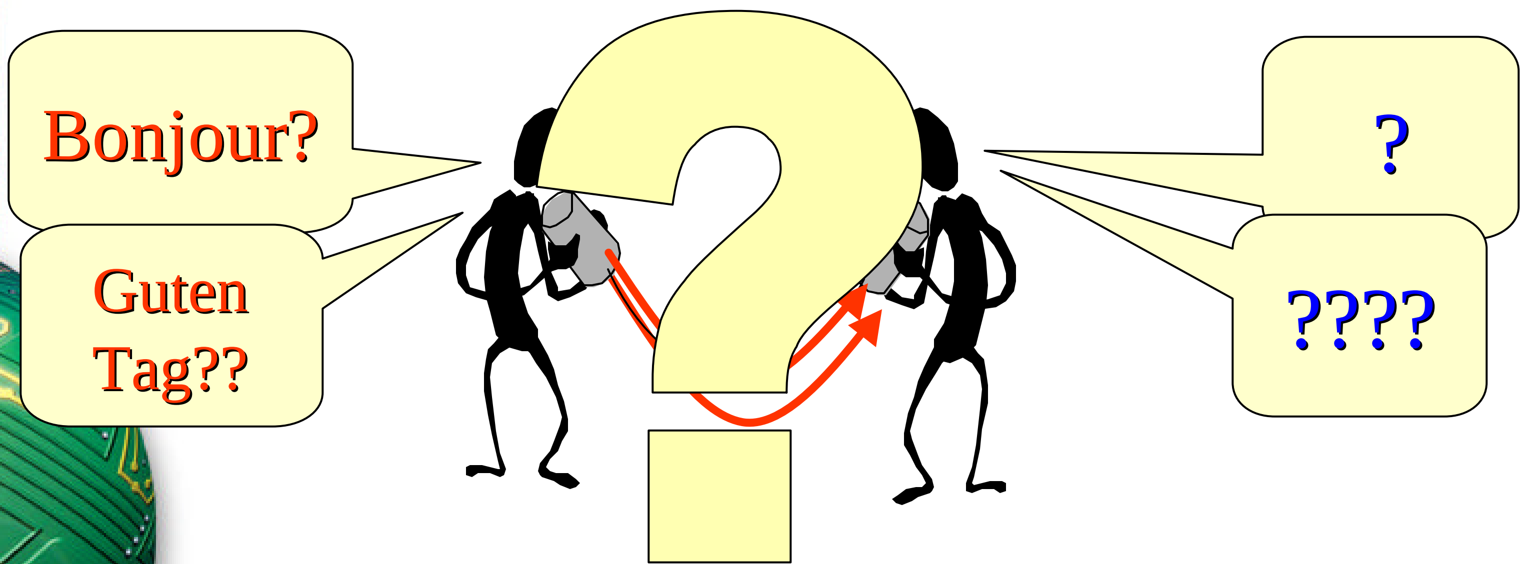
Sr. Area Manager - PLC/HMI

Rockwell Automation

Allen-Bradley
Reliance Electric
Dodge
Rockwell Software
Rockwell Automation

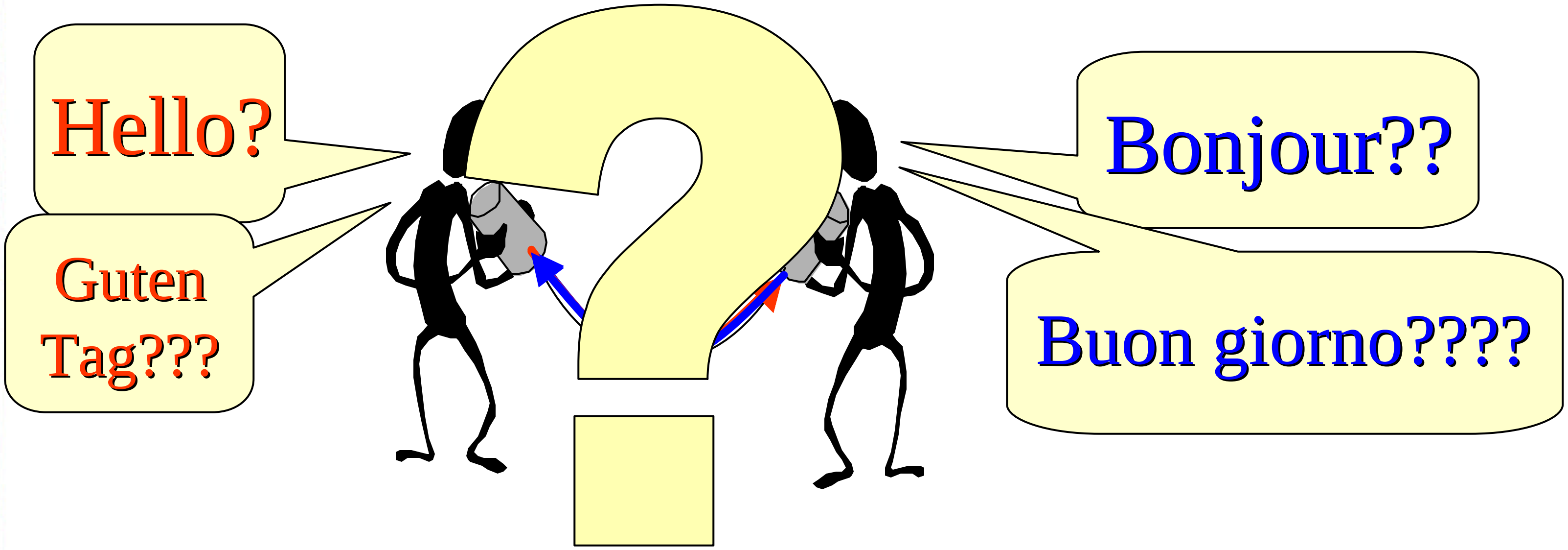
Common Language is everything...





Partners in Manufacturing Excellence

“Ethernet is not Ethernet is not Ethernet”

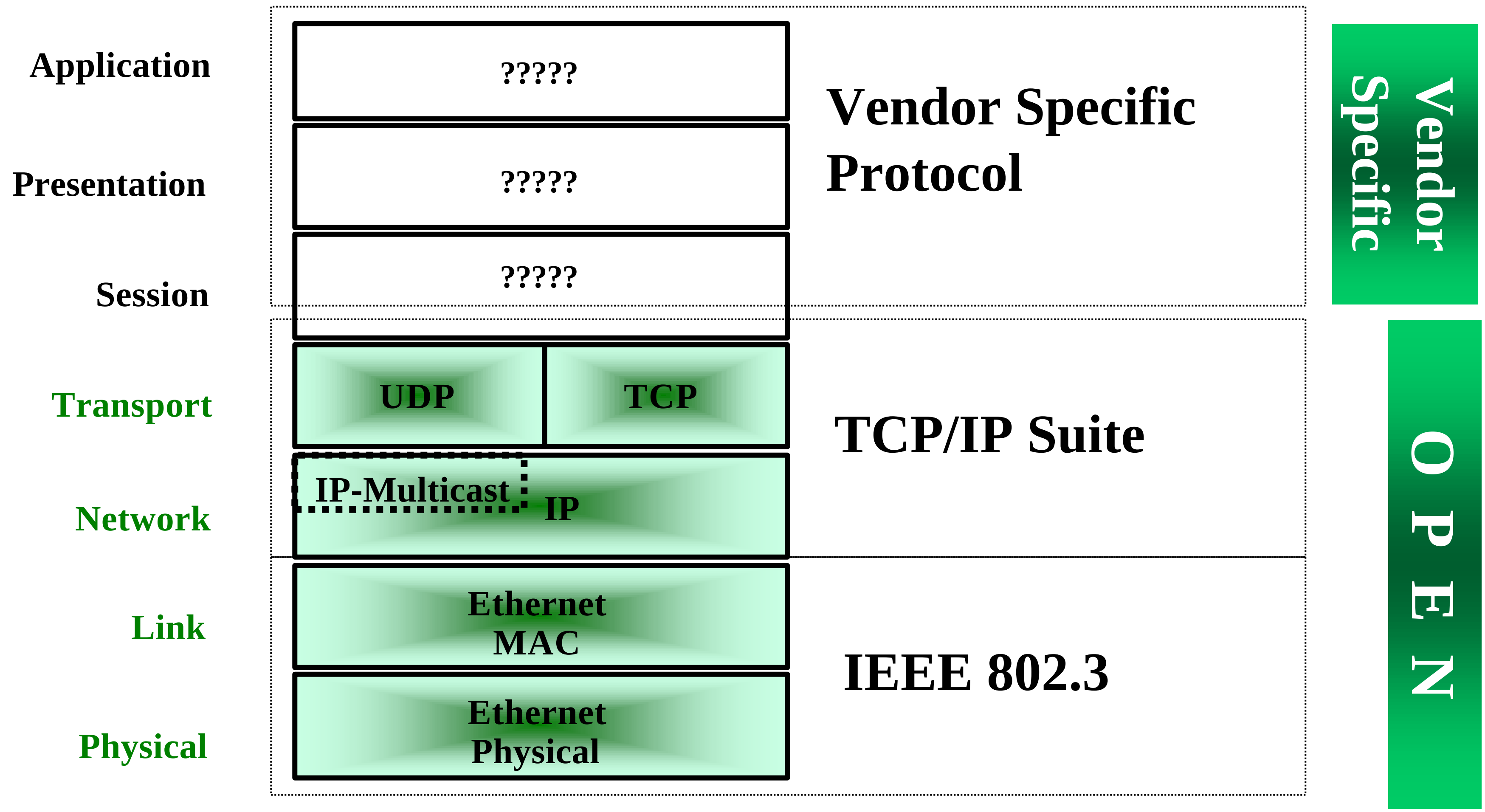


Partners in Manufacturing Excellence

<u>Question</u>: Why can’t industrial automation equipment from different vendors communicate to each other on an Ethernet network today?

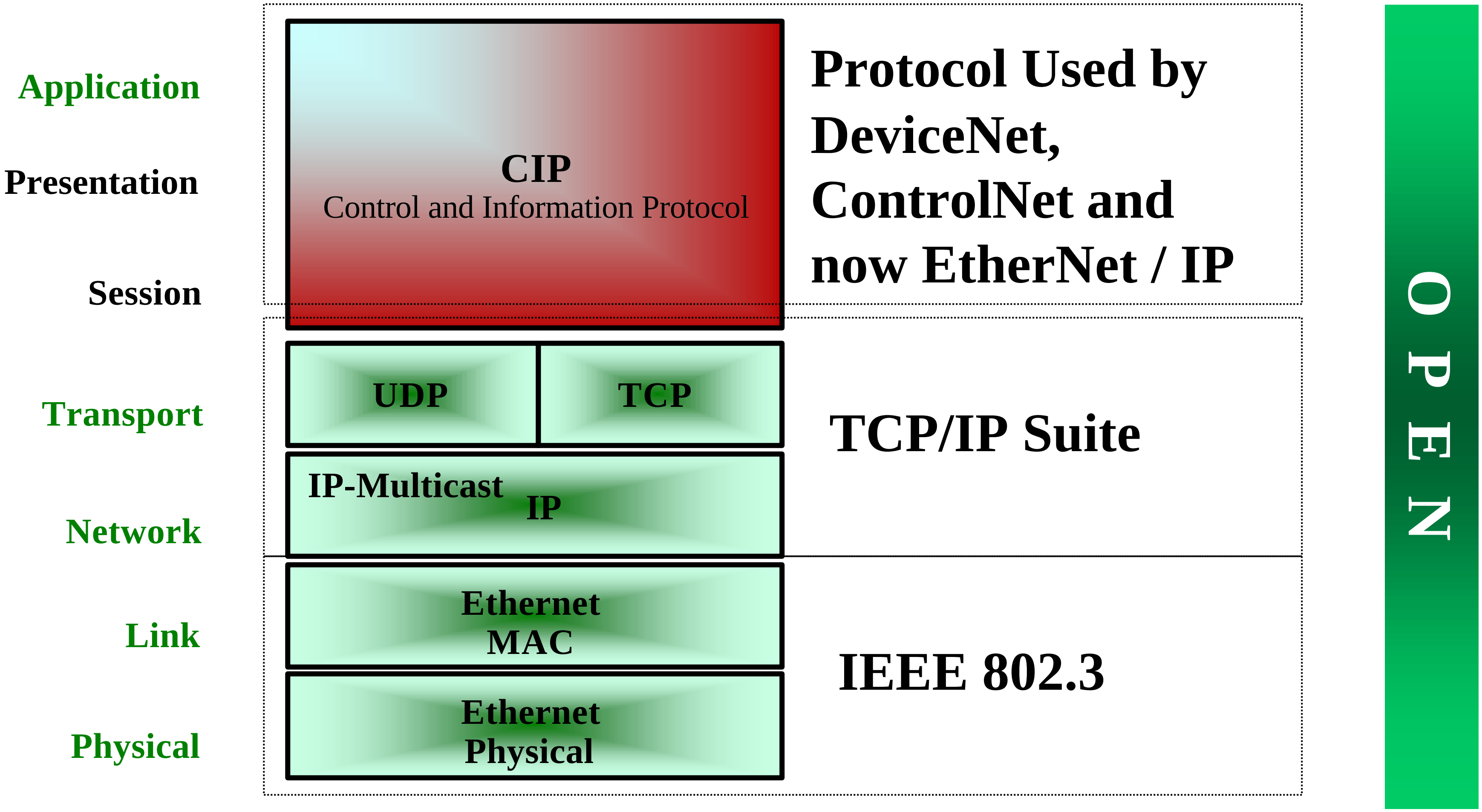
<u>Answer:</u> They don’t use the same application layer protocol !

Ethernet TCP/IP Stack



There is no open "standard" application layer for real-time control over Ethernet….UNTIL NOW !!!

EtherNet / IP !!!



Control and Information Protocol (CIP) -
An Object Orientated Application Layer Protocol

Partners in
Manufacturing
Excellence

EtherNet/IP

(IP…Industrial Protocol)

Open Networking Standard Managed by:

**Open DeviceNet Vendor Association (ODVA),
ControlNet International (CI) and the
Industrial Ethernet Association (IEA)**

ODVA, ControlNet International and Industrial Ethernet Association Team Up!

Partners in Manufacturing Excellence

- **CI and ODVA have teamed to jointly Sponsor & Support the Open EtherNet/IP Standard for Industrial Applications**
  - First Open Organization … Over 400 Members Worldwide … to Endorse an Industrial Ethernet Application Layer for Control
    - **ODVA - www.odva.org**
    - **ControlNet International - www.controlnet.org**
  - Joint Special Interest Groups (SIGS) have been formed to manage Ethernet Transport Layer, Application Layer (Systems) Specs, Device Profile Specs & Conformance Testing
- **Industrial Ethernet Association (IEA)**
  - Leading Web-based Association Focused on Industrial Ethernet
    - **IEA - www.industrialethernet.com**
  - Serve as a Virtual Storefront for EtherNet/IP

ODVA and CI manage the technology

- Joint SIG will manage spec enhancements
  - ODVA and ControlNet International Members can participate
  - One company, one vote
  - Supermajority (70%) required to adopt proposals
  - Technical Review Boards from both organization must approve
- Joint Conformance SIG will develop conformance testware

ODVA Labs will conformance-test EtherNet/IP Products

Partners in Manufacturing Excellence

Testing to begin in Fall, 2000

- ASTEM (Kyoto, Japan)
- University of Michigan (Ann Arbor)
- University of Warwick (Coventry, England)

EtherNet/IP
CONFORMANCE TESTED

Technology will be free !!

- ODVA and ControlNet International (CI) have agreed to make the technology free and downloadable from multiple Web Sites
  - Specifications (available now in ControlNet spec.)
    - CIP Protocol, Object Libraries, TCP/IP Encapsulation
  - Example (source) Code for a simple I/O server type product (available end of July)
- Membership in ODVA and CI is recommended but is <u>not</u> required
  - No royalty
  - Unique “Vendor ID” is required for Conformance
    - assigned by ODVA / CI for a $100 registration fee

Uses Commercial Off-the-Shelf Technology

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- Uses standard Ethernet chip sets
  - No changes to standard Ethernet access protocol
- Uses the standard TCP/IP protocol stack
  - Standard BSD sockets interface
- Allows for normal operation of other standard TCP/IP applications
  - FTP, HTTP, SNMP, DHCP, BOOTP, DNS……...

ODVA, CI and IEA promote EtherNet/IP

- ODVA, CI and IEA co-promote rapid adoption of EtherNet/IP
- Training is being offered for product developers
  - Next class (July 24, 25) in Cleveland
    - Another class in September in Milwaukee
    - 2 day developer training (for a nominal fee)
- Free e-mail technical support service - Ask Mr. EtherNet/IP
- Sponsor Trade Show Demonstrations
- Speakers' Bureau
- Joint ControlNet Intl/ODVA Ethernet SIG
  - Guidelines for Vendors
  - Guidelines for Users
  - Collect and Publish Performance Benchmarks

Control & Information Protocol

- What is CIP?
  - Object-based approach to designing industrial control devices
  - Network independent application layer
    - Supports a common set of data types, object libraries, and profiles across several different networks
  - Standard set of services for accessing data and controlling device operation
- Supports the Producer / Consumer data model
  - Also called “publisher / subscriber”

Control and Information Protocol (CIP)

- **C**ontrol and **I**nformation **P**rotocol
- The **Control** protocol is for real time I/O
  - also called Implicit messaging
- The **Information** protocol is for message exchange
  - also called Explicit messaging

The CIP specification for Control over Ethernet is available now in the ControlNet Specification !

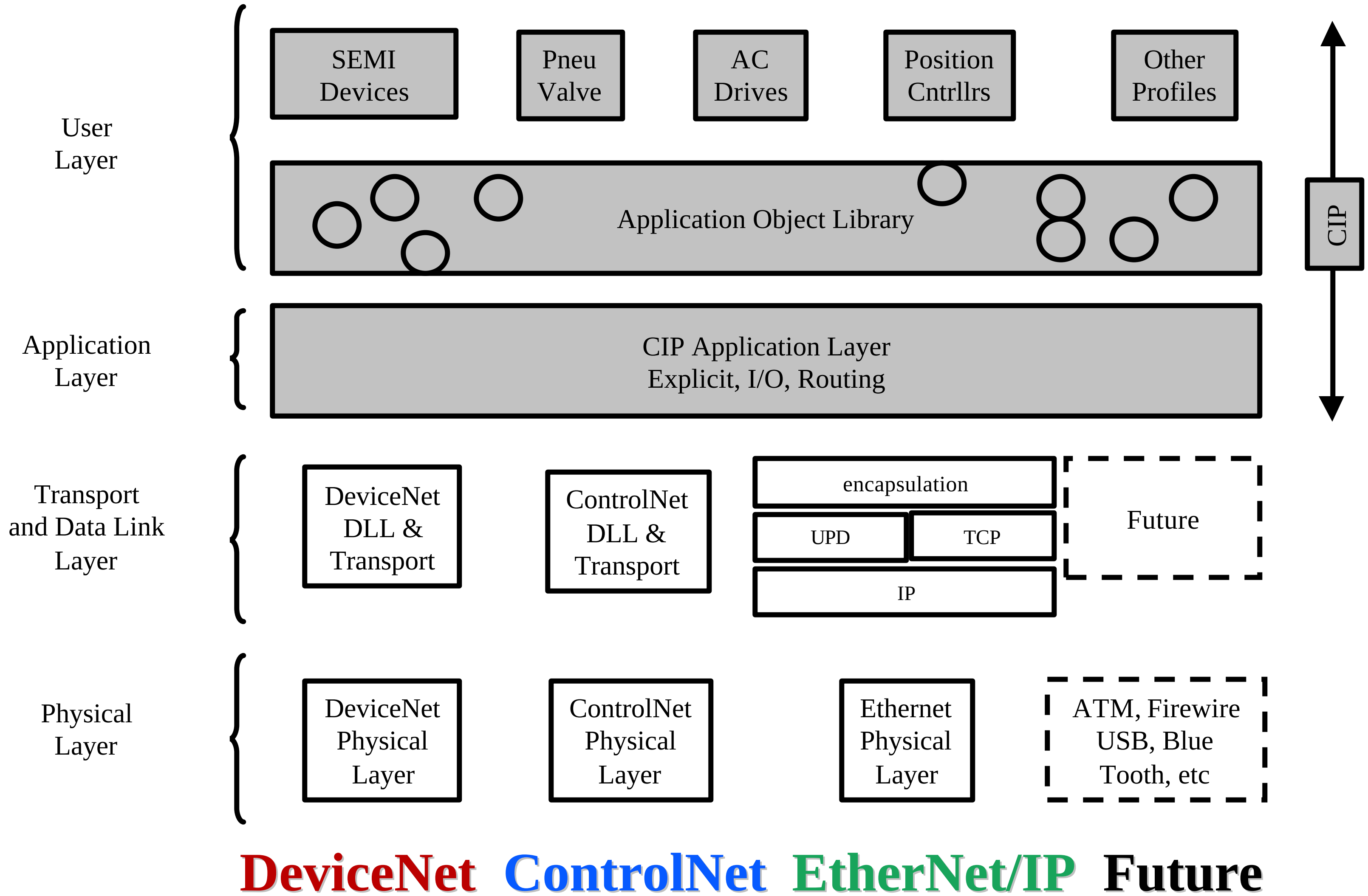
CIP Architecture

- Explicit Message
  - Each message contains all the information that the recipient requires in order to handle the message correctly (explicit content)
    - Message content is not known in advance by the endpoint
  - One-time transport of a data item
    - Also used with non-data services (I.e. Commands)
  - Simple Request / Response messaging
    - Client sends a request message / server replies
  - Operates in both connected and unconnected modes
    - Used for point-to-point connections only
  - Sent over Ethernet as TCP / IP frame

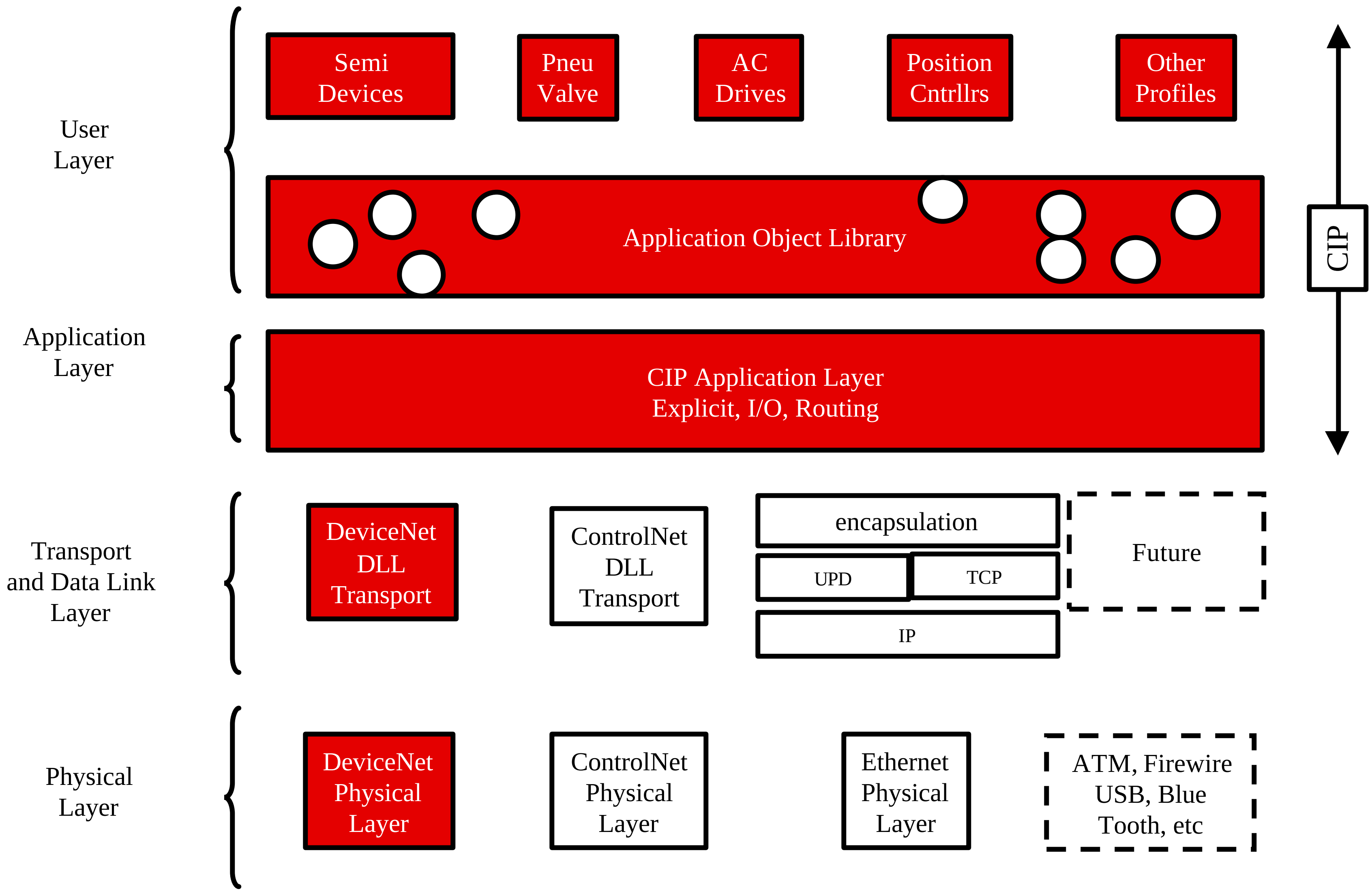
CIP Architecture

- Implicit (I/O) Message
  - Message content is known in advance by connection endpoints (implicit content)
    - Both parties know in advance which data is being transferred
    - Messages do not contain information that instructs the recipient how to handle the content
  - Regular, repeated transport of a specific set of data items
    - Usually used for time-critical I/O data
  - Supports multiple transport classes and data triggers
    - Unacknowledged (no response), acknowledged (consuming connection responds), Verified (consuming object responds), Unacknowledged with sequence count
    - Polled, cyclic, change-of-state, application triggered, etc.
  - Operates in connected mode only
    - Supports pt-to-pt and multicast connections
  - Sent over Ethernet using UDP / IP frame for maximum efficiency

CIP Networks share a common Industrial application layer Protocol

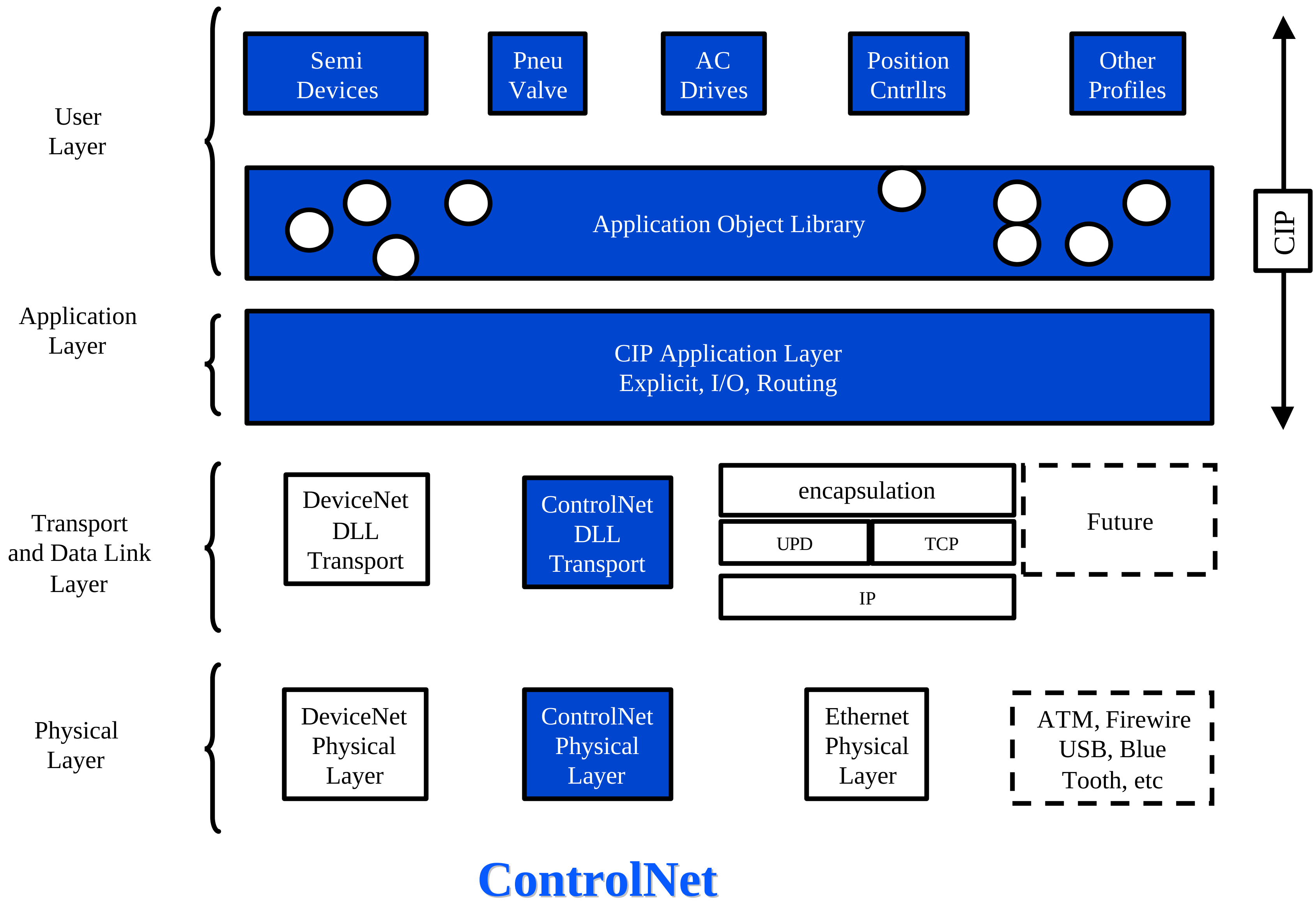


This is DeviceNet



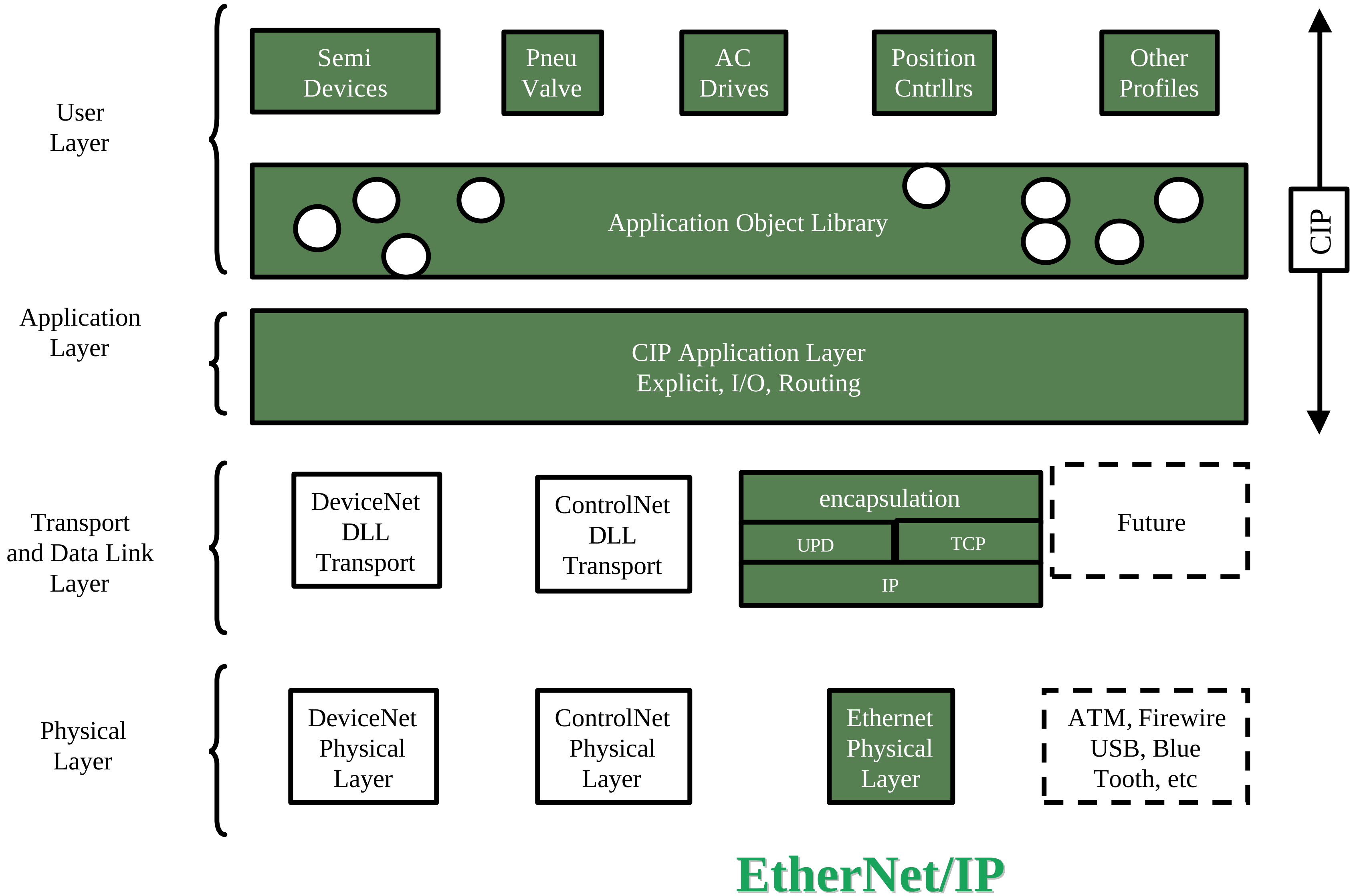
DeviceNet

This is ControlNet



This is EtherNet/IP

(IP stands for Industrial Protocol)



CIP Architecture

- Producer/Consumer Model
  - A Producer is a sender of data
    - Producers transmit data packets on the network along with a unique identifier that indicates the <u>packet</u> content (<u>not</u> the source address)
  - A Consumer is a receiver of data
    - Any interested consumers can pick data off the network by filtering the packet identifier
  - Model allows for very efficient "multicasting" of produced data
    - A producer can transmit a single frame that can be received by multiple consumers

Object Modeling

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- Applying Object Modeling to Devices
  - A device is described as a collection of objects
  - Each distinct type of object belongs to a specific **Class**
  - Objects that belong to the same class are called **Instances** of that class
  - Data items within an object are called **Attributes**
  - All data items (parameters and runtime data) can be addressed by **Class:Instance:Attribute**
  - **Services** may be directed at a specific instance or at the class, which affect all instances of the class

Object Modeling Example

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- Example: 2 *Instances* of the Object *Class*:*Human*

Class	Instance	Attribute	Value
Human	Mary	Weight	N/A*
		Age	N/A*
	John	Weight	180
		Age	42

Reading this attribute returns an Attribute_Not_Supported error response
(If you ask Mary her age or weight, you will not get a response)

Object Modeling

Partners in Manufacturing Excellence

- Device Profile
  - The specific combination of required and optional objects that define the operation of the device
  - The CIP Specification(s) define profiles for many standard industrial control devices; permitting interchangeability and interoperability through common interface definitions
  - Standard Device Profiles may be extended by vendor-specific attributes and objects

Object Modeling

- Electronic Data Sheet (EDS)
  - Open standard method used to describe and document the specific objects and attributes that a device supports
    - Is both Human and Computer readable
  - Allows for standardized device configuration
    - Allows for automated device configuration
    - Both on-line and off-line
  - Allows for standardized remote monitoring of device parameters

General CIP Object Model

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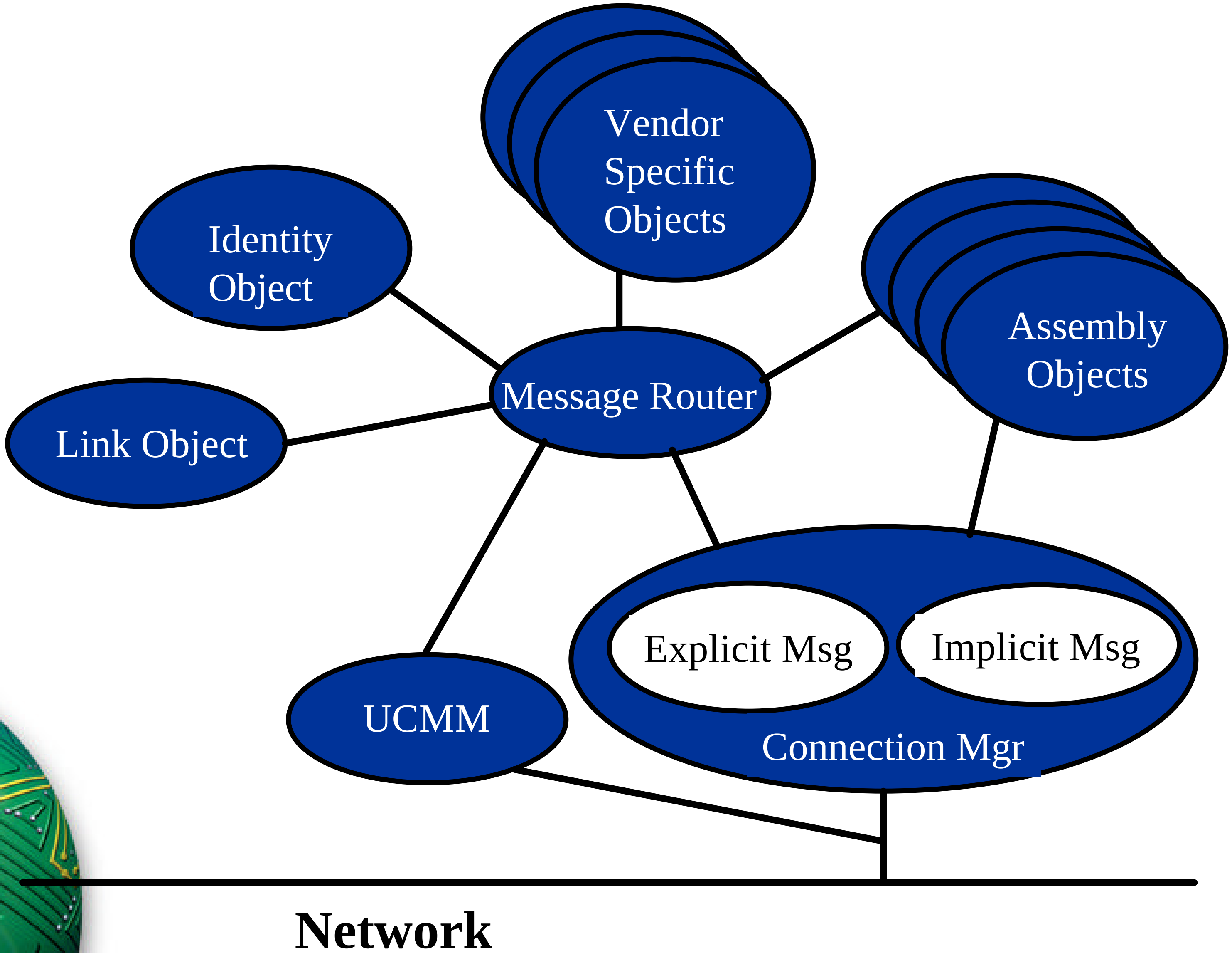
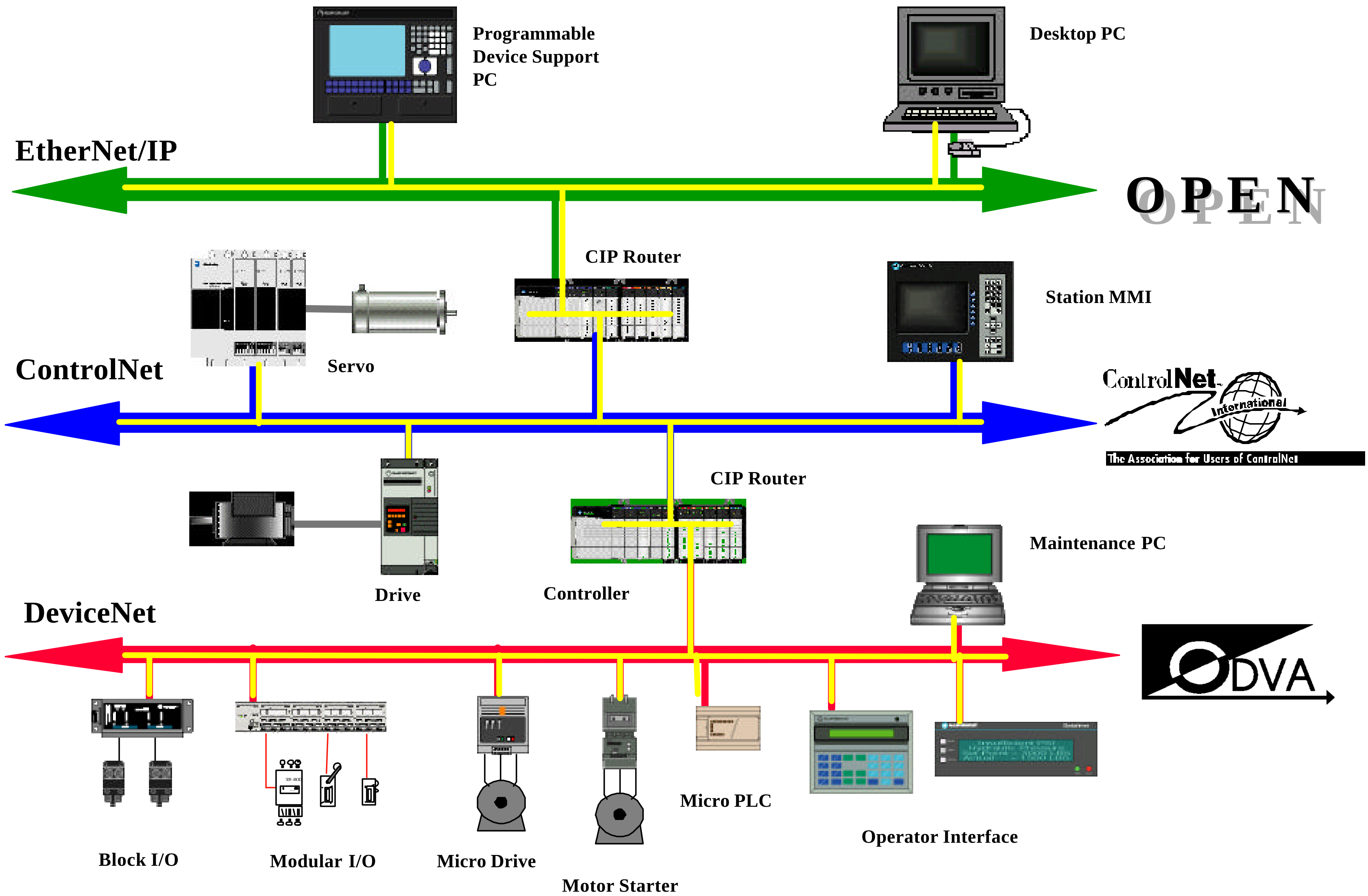


CIP Architecture

Partners in Manufacturing Excellence

- Messaging Paradigms
  - Unconnected Messaging
    - Allows “temporary” access to all devices
      - Access to device resources can’t be “blocked” or held by any one device
      - Allows access to devices for intermittent “one-time” non-time critical services
    - Example: When you want to enter the freeway, there is usually space for one more car (but you may wait awhile)
  - Connected Messaging
    - Allow “persistent” access to devices
      - This allows customers to make sure that device resources can be “reserved” or “guaranteed” for important applications
    - Example: A train can “reserve” the use of the track in advance

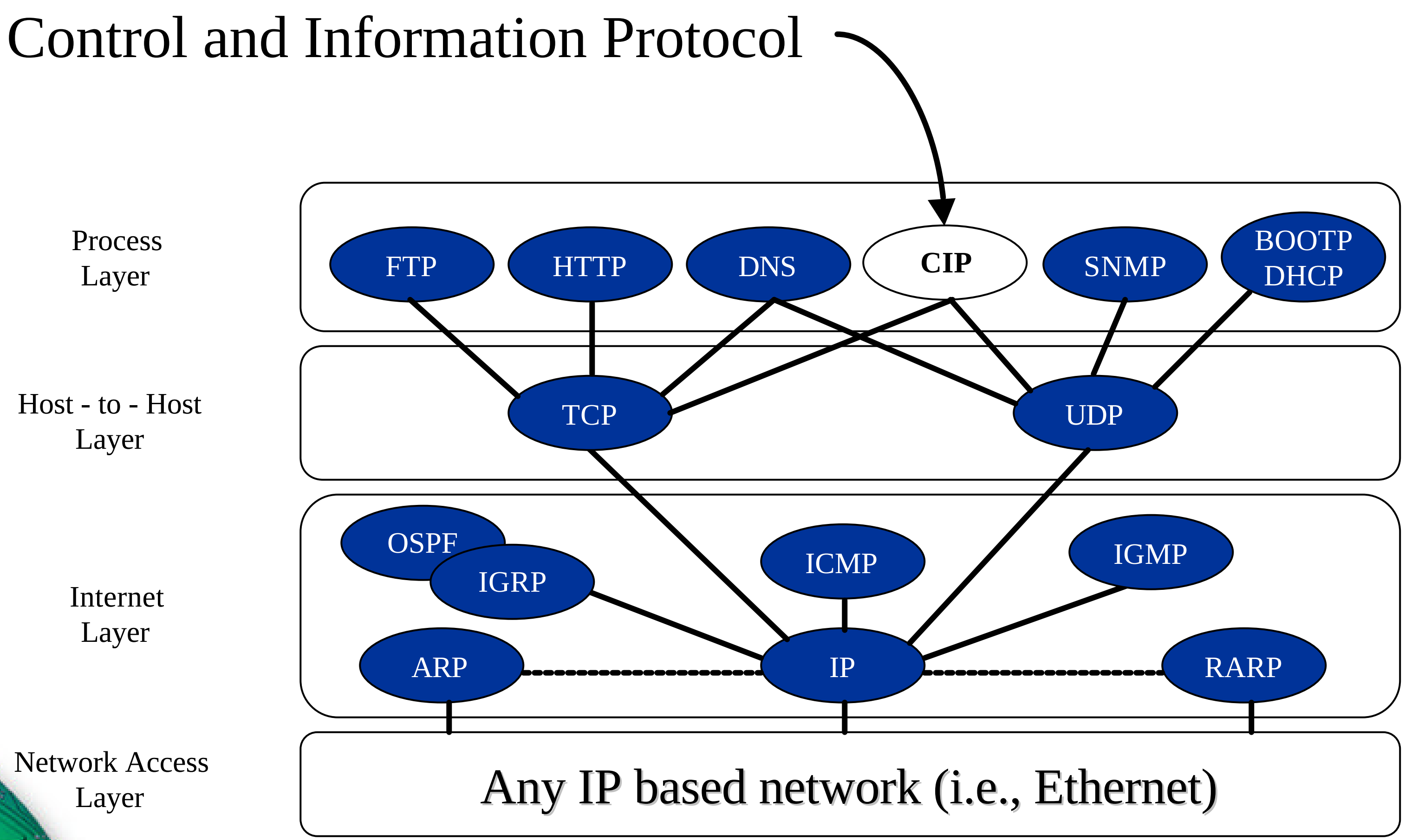
CIP Allows For Seamless Routing



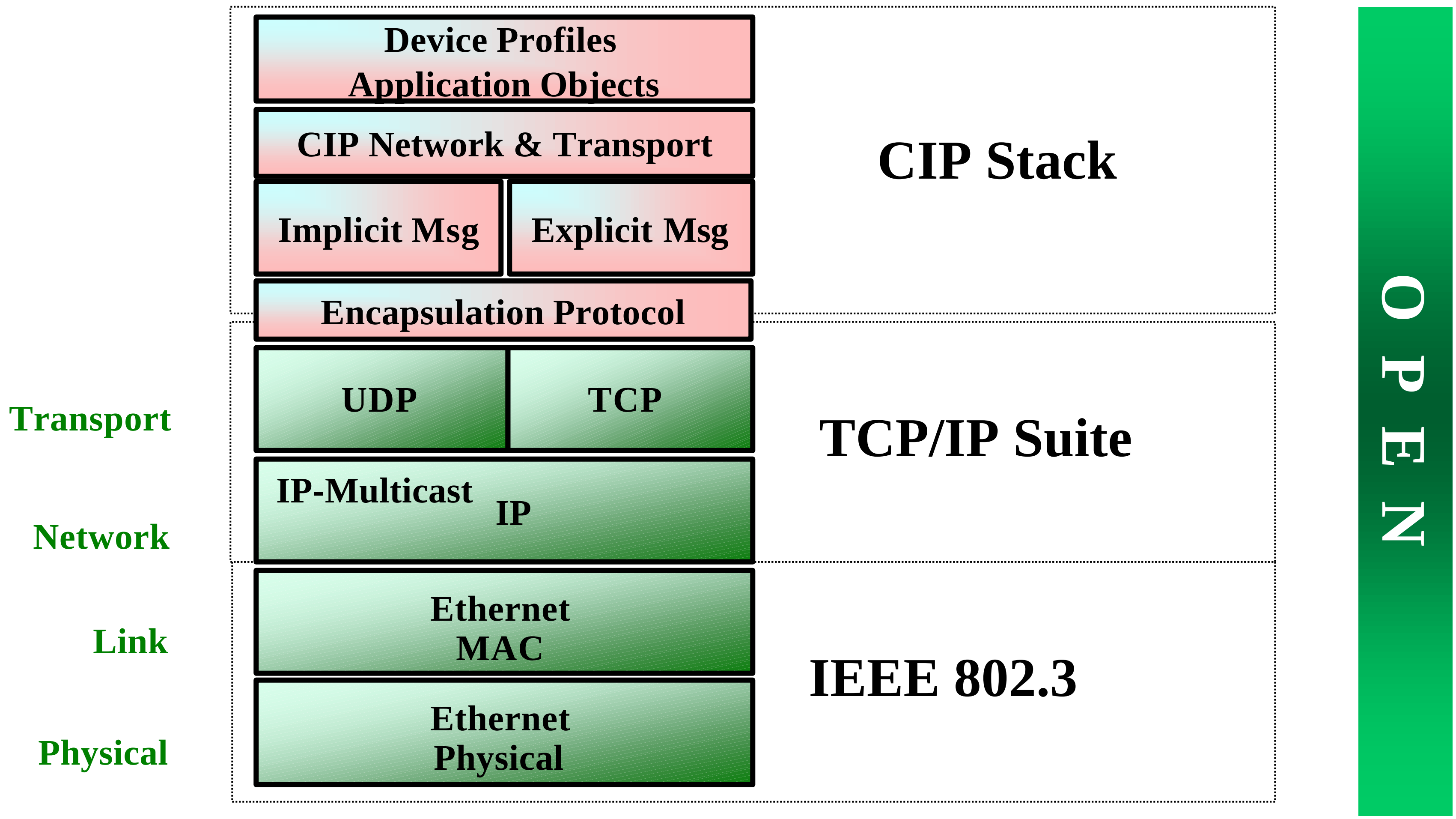
Control and Information Protocol (CIP)

- Protocol is globally supported by more than 400 companies today building ControlNet, DeviceNet and EtherNet/IP products
  - ODVA, CI, IEA
- ODVA & CI provides conformance and interoperability testing
- CIP provides seamless integration between EtherNet/IP, ControlNet, DeviceNet
- CIP brings the Internet to the device level
- CIP is an IEC 61158 and Cenelec EN50170 standard
- CIP provides high performance, P/C based
- CIP is FUTURE proof

The TCP/IP Model



EtherNet / IP Layered Model



Control and Information Protocol over TCP/UDP/IP Ethernet

EtherNet/IP Product History

- EtherNet/IP has been used for interlocking between processors for several years (using explicit messaging)
  - Included in ControlNet Specification since Mar '98
  - Supported today in the PLC5, SLC and ControlLogix processors from Rockwell Automation
- Products supporting implicit (I/O) messaging will start shipping in Fall 2000

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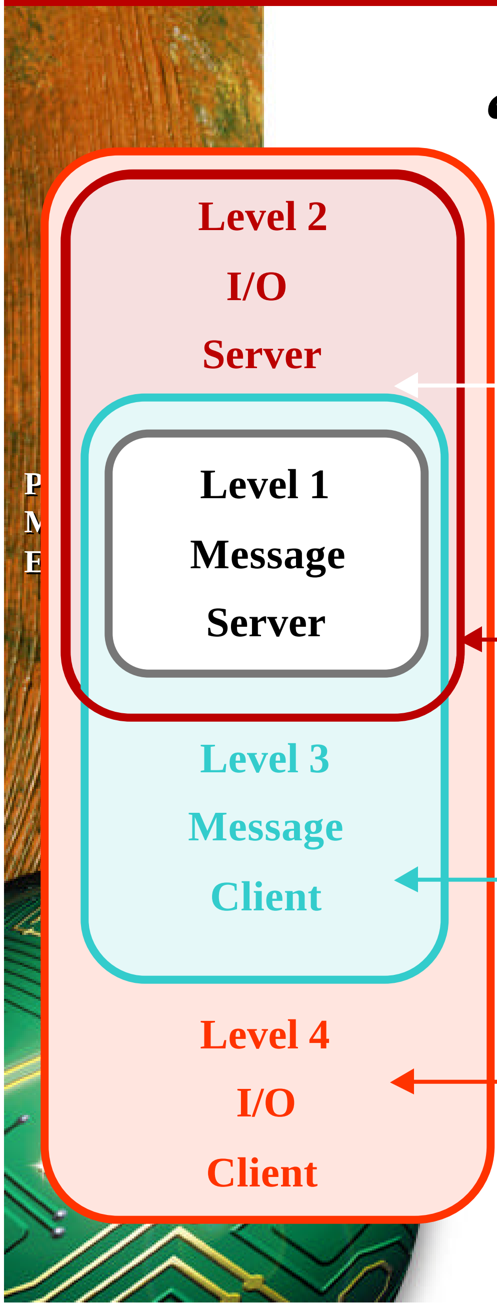
EtherNet/IP Functional Model



"Only implement the functionality you need"

- **Level 1 (Explicit Message - Server / Target only)**
  - **Used for explicit messaging applications only**
  - **Acts as a target for connected and unconnected explicit messages**
  - **Example: Program upload / download, data collection, status monitoring, etc**
- **Level 2 (I/O Message - Server / Target only)**
  - **Adds I/O messaging support to Level 1**
  - **Acts as a "target" for both explicit and I/O messages**
  - **Example: Simple I/O devices, Pneumatic Valve, AC Drive**
- **Level 3 (Explicit Message - Client / Originator + Server / Target)**
  - **Adds Client support to Level 1 explicit messaging applications only**
  - **Acts as a target and an originator for messaging applications**
  - **Example: Computer interface cards, HMI and MMI devices**
- **Level 4 (I/O Message - Client / Originator + Server / Target)**
  - **Adds I/O message origination support to Level 1,2 and 3**
  - **Acts as a target and an originator for explicit and I/O messages**
  - **Example: PLCs, I/O Scanners, Logic Controllers**

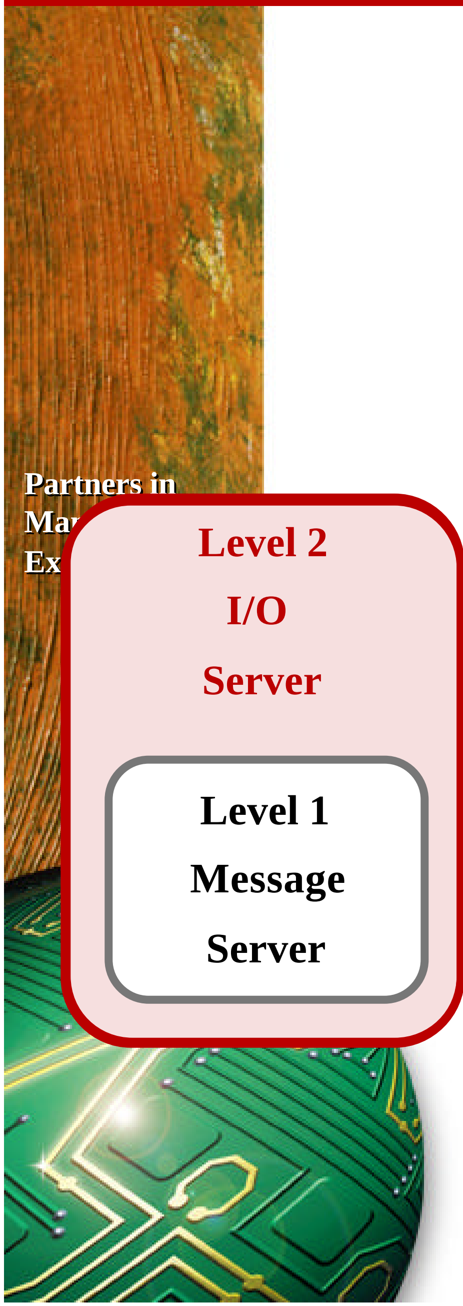
What Do I Need to Get Started?

- The Example Code (or “CIP Stack”)
  - The Example Code contains the ‘C’ source code required to implement the CIP protocol running on top of a TCP/IP Ethernet stack
  - This includes support for CIP “Level 2” required objects
  - Also include support for a general purpose “assembly object”
- The Example Code has been designed to support;
  - VxWorks RTOS (from Wind River)
  - TCP/IP stack (from Wind River)
  - And Microsoft PC platform running NT4.0

What Do I Need to Get Started?

- The developer needs to provide the following items;
  - The appropriate Ethernet hardware platform
  - Any optional product or vendor specific CIP application objects
  - TCP/IP stack with a “Berkley Sockets” (BSD) interface
  - A multitasking real time operating system (RTOS)
  - Any other required or optional TCP/IP applications
    - HTTP, SNMP, FTP……….

Free Example Code



- In an effort to give vendors a “jump start” on an EtherNet/IP product development, ODVA and ControlNet International have agreed to make the “Level 2” Example Code available free of charge!
  - Available for download from ODVA, CI and IEA web sites by the end of July 2000
- Level 1 (Explicit Message - Server / Target only)
  - Used for explicit messaging applications only
  - Acts as a target for connected and unconnected explicit messages
  - Used in products to do program upload / download, data collection, status monitoring, device configuration, etc
- Level 2 (Implicit Message - Server / Target only)
  - Adds **Implicit (I/O)** messaging support to Level 1
  - Acts as a “responder” for both **explicit and Implicit** connected and unconnected messages
  - Used to build simple I/O server products

What If I Need Additional Help?

- Education
  - – Developer training classes are held every 2-3 months in different locations around the world
    - Contact ODVA / CI for details
    - www.odva.org ***or*** www.controlnet.org
- Ask Mr. EtherNet/IP
  - – Email support from ODVA / CI
- OVDA and CI web site contains a list of companies that can provide a variety of design support services for EtherNet/IP

Robotic Industries Association

EtherNet/IP

An Open Standard for Real-Time Control Over Ethernet

Rockwell Automation

Section Five

Open Architecture: Where should we spend our efforts?

Presented by:

William Kneifel
Development Manager
Trellis Software & Controls

Open Architecture:

Where should we spend our effort?

Bill Kneifel
billkneifel@trellissoftware.com

TRELLIS
Software & Controls, Inc.

Presentation Overview

- Identify OAC domain to focus on.
- Leverage technologies that already exist today.
- Tackle key business issues.

Open Architecture

- **What is it?**
- **Why do, or should, we care?**

To some people, *Open Architecture*
means working with a Wintel platform.

There is not a single universal definition.

- Probably means different things to these domains:
  - Research community
  - Industrial application community

Open Architecture - What is it? Why care?

- Research Community
  - ***Open source code***
  - ***Subsystem replacement***
  - ***Defined interfaces***
  - Sensor integration
  - Algorithm development
    - Servo control
    - Motion control
    - Process control
- Industrial Community
  - ***Externally defined interfaces***
  - Interoperability between robots and:
    - Enterprise
    - Remote monitoring
    - Configuration mgmt
    - I/O, PLCs, sensors
    - Technology controllers
    - Cooperating equipment

Open Architecture - What is it? Why care?

- Industrial Community
  - ***Externally defined interfaces***

  - Interoperability between robots and:
    - Enterprise
    - Remote monitoring
    - Configuration mgmt
    - I/O, PLCs, sensors
    - Technology controllers
    - Cooperating equipment

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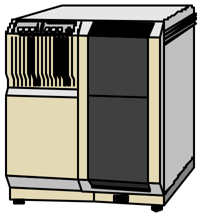
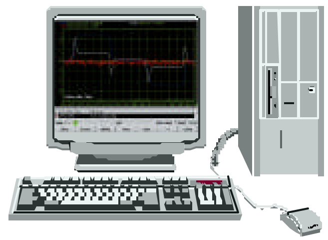
Interoperability Hierarchy

Enterprise Computer

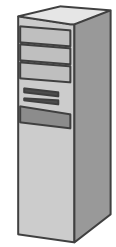


PC



PC

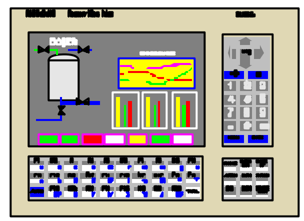
Servers



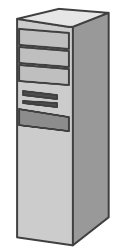
Enterprise

Cell Controllers

HMI

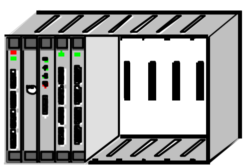


Servers

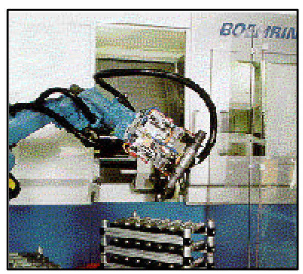


Field Bus - Cell

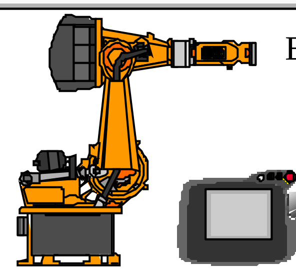
PLC



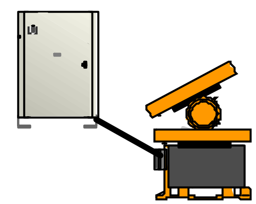
CNC Turning Cell



Robots



External Axis Controls

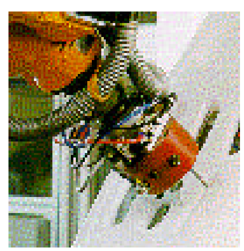


Pendants

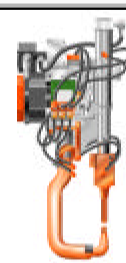
Device Bus

Laser Tool

Cutting Tool



Weld Gun



I/O Block

Key Technologies for Interoperability

- Many already exist and are available today *(do not need to reinvent)*
  - Networks
  - Thin client user interfaces
  - Hardware independence

Networks

- Field, Safety, and Sensor busses
  - Too many exist today – this is one challenge to interoperability
  - But, network hierarchy in factories is collapsing
  - Ethernet is gaining ground – how do we capitalize on this?
- Ethernet TCP/IP in place now
  - Open 100MB TCP/IP with robot controller (KUKA, FANUC)
  - Smart switches for efficient network topologies
  - Industrial Ethernet rapidly emerging
- Existing Layer 7 application protocols -- build on this
  - Modbus/TCP
  - ProfiNet
  - EtherNet/IP

Thin Client User Interfaces

- Enables common UI for set of dissimilar equipment
- Supports networked peripherals (e.g, pendants)
- Provide for easily maintainable remote capabilities

Hardware Independence

- Parallel busses today – ISA, PCI, PC-104
- Serial busses tomorrow
  - USB – PC related peripherals
  - IEEE 1394 – for high speed data streaming
  - Multiplicity of field busses
  - Ethernet – *strongest candidate for future*

Key Business Issues to Tackle

- Reduce Costs
- Reduce Development Time
- Work Globally

Business Issue – Reduce Costs

- Simplify factory infrastructure
- Improve system wide reliability & service
- Ease integration & application development

Our approach should accomplish these objectives. So what's a common denominator?

Interoperability

Business Issue – Reduce Development Time

- Adopt single interoperability protocol & profiles
  - Shrinks required application developer knowledge
    - Reduces number of supported I/O busses
    - Reduces number of technology controller interfaces
    - Reduces number of robot controller interfaces

- Adopt single interoperability network
  - Hardware and cabling availability improved
  - Can stock single set of cable, connectors, etc.

Reduced by Enhancing Interoperability

Business Issue – Global Approach Needed

- Robot companies sell globally, yet
  - Different protocols dominate in different regions
  - Sometimes even in different companies

- Therefore, global standards are highly desirable.

Learn from Organizations Involved in Networking

- Industrial Automation Open Networking Alliance (IAONA) / Interface for Distributed Automation (IDA)
- Industrial Ethernet Association (IEA)
- Modbus User's Group
- ControlNet International (CI)
- Open DeviceNet's Vendor Association (ODVA)
- Profibus International
- What are others?

Let’s Identify Our Objectives

- Create list of interoperability areas to address
- Identify the issues to tackle
- Identify benefits and prioritize list

Let's Develop a Strategy & Execute

- Global strategy
- Consistent & complementary to existing methods
- Create roadmap and plan to accomplish

Summary of Immediate Actions

- Focus on interoperability to reduce costs in the *industrial community*:
  - Establish relationships with other organizations.
  - Define interoperability problems to be solved.
  - Pursue global approaches, select one, and implement.

Near-Term Objectives Workshop

Section Six

Open Architecture Interfaces to Robot Controllers

Presented by:

Gary Rutledge
VP
Advanced Product Development
FANUC Robotics North America, Inc.

Open Architecture Interfaces To Robot Controllers

G. Rutledge

FANUC Robotics

With contributions from

Adept, Kuka, Motoman

KUKA

adept ADEPT TECHNOLOGY, INC.

MOTOMAN

FANUC Robotics

Characteristics of the Manufacturing Environment

Design Life
7 to 9 years

No maintenance
till 5000 hrs
service

Reliability

Vendor Pays for
Line down time

Reparability

Any Repair
less than
2 hours

Parts Available
7 to 10 years

The PC Augmented Architecture

Closed Real Time Environment

Motion Control

Process Control

I/O Control

Real-time Environment

Strong Standard Connection

Microsoft Standard Open Environment

Graphic User Interface

Data Analysis/ Reporting

Communications

Microsoft Environment

Resolving the Issues

Reliability

Closed Real time System

Proprietary Real time Kernel

Non Microsoft Kernel

Reparability

Vendor Manufactured Hardware

Vendor Controlled Hardware

What do we mean by “Open Architecture”

OMAC Definition:

..A modular, standards based, open architecture controller (*in which)* modules can be added, replaced, reconfigured, or extended based on the functionality and performance required.”

“..a commitment to A PLATFORM + OPERATING SYSTEM + COMPILER + LOADER + INFRASTRUCTURE SUITE is necessary for it to be possible to swap modules.”

OMAC API WD V0.16

OMAC doesn't work for Robots

- Doesn't match customers expectations
  - Safety
  - Reliability
  - Repeatability
  - Robots are not like CNC machines
  - Robot Industry is not like the CNC industry

- Doesn't make economic sense
  - 11, 300 total units in the US is not enough to generate a 3rd party industry.

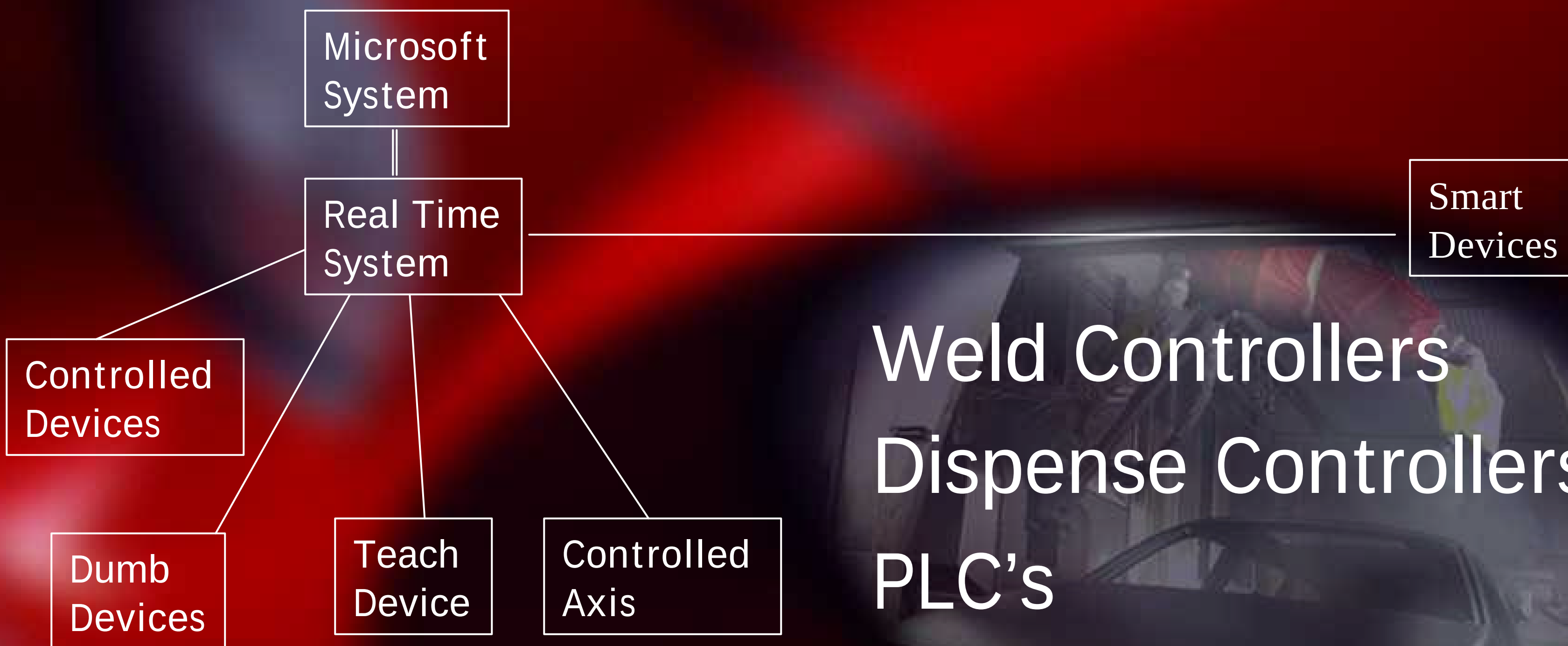
Open Should mean:

Interoperability

- **Definition:**

Plug and play interconnection with
peripheral equipment,
plant data systems and
graphic displays.

Peripheral Integration



Weld Controllers

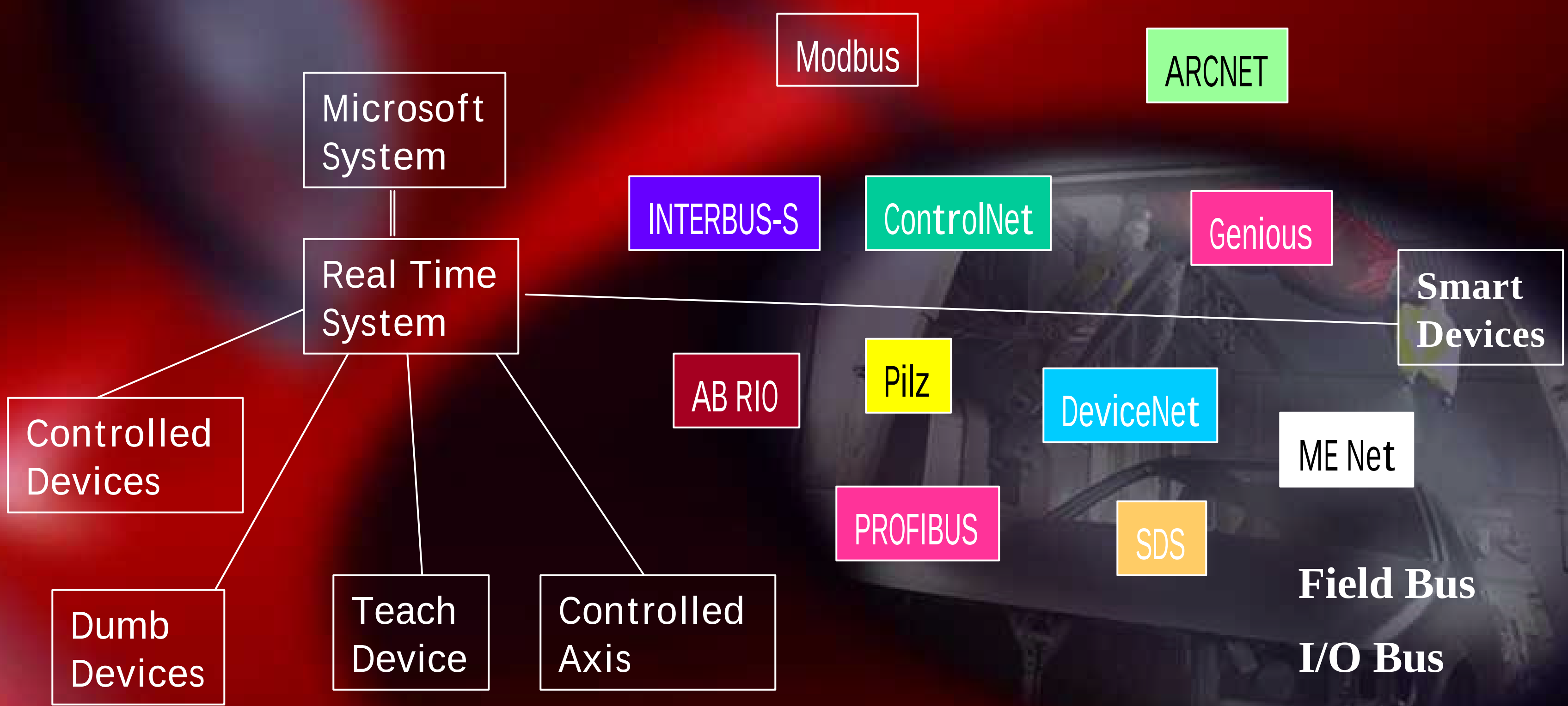
Dispense Controllers

PLC's

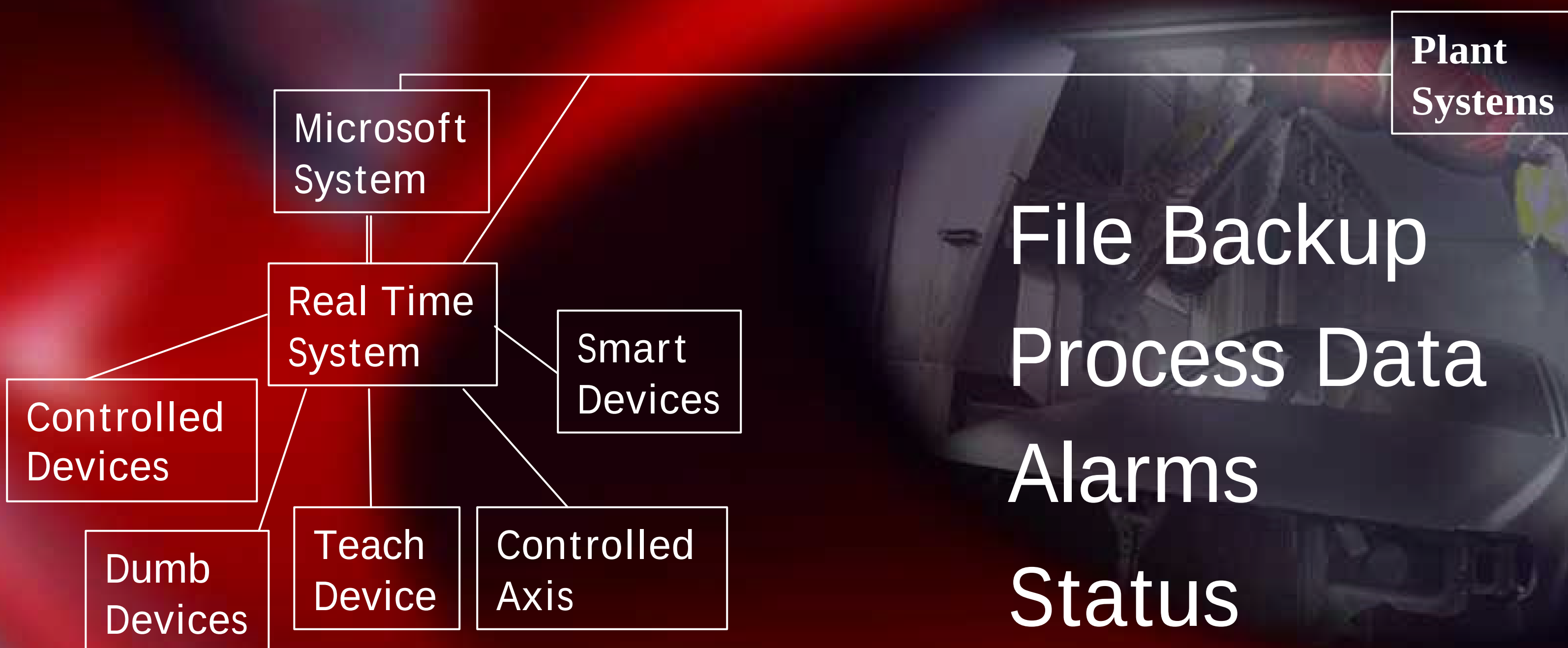
Smart Sensors

Plug and Play Peripheral Integration

The Industrial
Single word Oxymoron: STANDARDS



Integration with Plant Systems



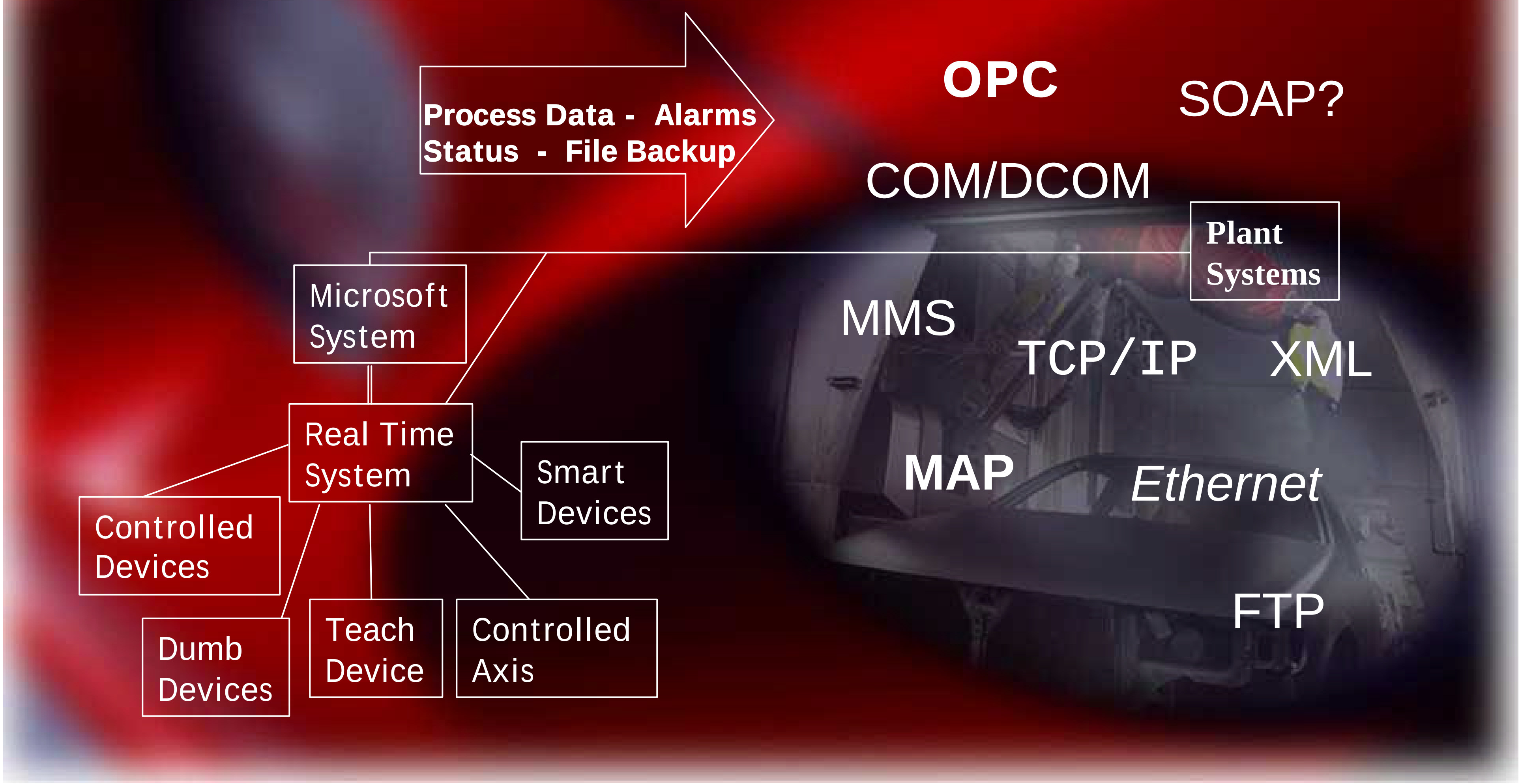
File Backup

Process Data

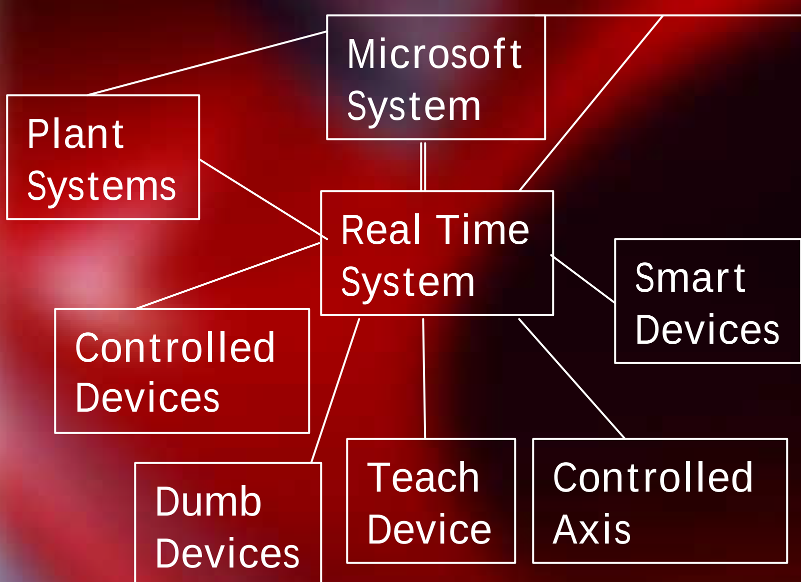
Alarms

Status

Plug and Play Integration with Plant Systems



Graphic Display Integration



Graphic Display

Plant Status Displays

Production Data

Equipment Status

Diagnostic Data

Plug and Play Graphic Display Integration

Wonderware

Microsoft Visual Basic

CIMPLICITY®

Intellution

OPC

Microsoft System

Plant Systems

Real Time System

Graphic Display

Smart Devices

Controlled Devices

Dumb Devices

Teach Device

Controlled Axis

HTML

XML

Plug and Play Standards

Peripheral equipment,

Plant data systems

Graphic displays.

Requirements

- Broadly Applicable Single Public Standard
- Global
- Long Lived
- Low Cost
- High Value
- Extensible
- Defined behavior under error conditions
- Validation test suite

Recommendation

- Undertake an initiative to identify/develop a suitable standard for
  - Peripheral Integration
  - Data System Connection
  - Graphic Display presentation

Open Architecture Interfaces To Robot Controllers

G. Rutledge

FANUC Robotics

With contributions from

Adept, Kuka, Motoman

Meeting Customer Expectations

- Customers Demand Consistent Performance
  - Works all the time
  - Works the same every time
  - No surprises
- Making Consistency Happen
  - Reliability, Repeatability, Safety require performance validation under all conditions of acceptable use.
  - Extent of validation governed by impact of change
  - Validation effort is frequently equal to or exceeds development effort.

Performance Validation is a Killer

- The CNC model doesn't exist in the Robot Industry

CNC

Control Vendor	Machine Integrator	Customer
	Validation	

Robots

Control Vendor / Machine Builder	Integrator	Customer
	Validation?	Validation?

The Economics of the Robot Industry

The Open PC model does not work in Robotics

11,300 robots vs. 100,000,000 Pc's per year
Robots are installed and not touched for 5 years

$1000 of 3rd party content on every robot sold in 1999 would support about 90 people.

Near-Term Objectives Workshop

Section Seven

RIA and OPC XML Efforts

Presented by:

Sushil Birla
Engineering Group Manager
General Motors Corporation

RIA & OPC XML Efforts

Sushil Birla

GM POWERTRAIN

GM CRW
CONTROLS • ROBOTICS • WELDING

Outline

- About OPC
- OPC Charter
- Overview OPC Standard Interfaces
- XML-based Development activities
- Summary

What Is OPC?

OPC is an industry standard created with the collaboration of a number a leading worldwide automation and hardware software suppliers working in cooperation with Microsoft. The organization that manages this standard is the OPC Foundation. The Foundation has over 220 members from around the world, including nearly all of the world's major providers of control systems, instrumentation, and process control systems.

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OPC Charter

To develop an open and interoperable interface standard, based upon the functional requirements of Microsoft COM, DCOM and Active X technology, that fosters greater interoperability between automation/control applications, field systems/devices, and business/office applications.

OPC standard interfaces

- OPC Data Access 1.x
- OPC Data Access 2.03
- OPC Alarms & Events 1.02
- OPC Historical Data Access 1.x
- OPC Batch 1.x
- OPC–XML for DA 2.x – under development
- OPC Data Access 3 – under development

OPC XML - Development Activities

- OPC–XML for DA 2.x
  - "XML"-izing almost the same spec
  - Opportunity to get rid of problems in old DA 2
  - Expected to evolve model/template for other interfaces.
- OPC Data Access 3 expected to be in XML
  - Strong data typing
  - Complex data (structures)
  - Commands
  - IO

OPC-XML for Data Access DA 2 Schema

- Key services
  - DataRequest //may cover SubscriptionRequest
  - DataResponse //may cover SubscriptionReply
  - WriteRequest
  - WriteResponse
  - CancelDataRequest
  - CancelDataResponse
  - BrowseRequest
  - BrowseResponse

OPC-XML for DA2 - Key Element Types

- Item
- Value
- ErrorList
- Error
- ErrorCode
- ErrorText
- Branch
- Leaf
- .....

OPC-XML for DA2 - Element Type: Value

```
<ElementType name = "Value" ...>
        .......
    </AttributeType>
    <attribute type="Quality" default="3" />
    <attribute type="Substatus" default="0" />
    <attribute type="Limit" default="0" />
    <attribute type="VendorQuality" default="0" />
    <attribute type="Timestamp" />
    <attribute type="type" />
</ElementType>
```

OPC-XML for DA2 - Element Type: Item

```
<ElementType name = “Item” ...>
        ……
      </AttributeType>
    <attribute type=“ItemID" />
    <attribute type=“ClientHandle" />
    <attribute type="RequestedDataType" />
    <attribute type=“Deadband" />
    <attribute type=“Value" minOccurs=“0” />
    <attribute type=“Error" minOccurs=“0” />
</ElementType>
```

OPC-XML for DA2 - Element Type: DataRequest

```
<ElementType name = “DataRequest” ...>
        ……
    </AttributeType>
    <attribute type=“Locale" />
    <attribute type=“TransactionID" />
    <attribute type=“TransactionSentTime" />
    <attribute type=“EchoItemID" default=“0” />
    <attribute type=“ErrorAsRef" default=“0” />
    <attribute type=“ItemIDPrefix" />
    <attribute type=“ExpireTime" />
    <attribute type=“Timestamps" />
    <attribute type=“UpdateRate" />
    <attribute type=“Callback" />
    <attribute type=“Deadband" />
    <attribute type=“Item" />
</ElementType>
```

Roles of XML in OPC Work

- XML as a Data Exchange Language
- XML as a Schema Description Language
- XML as a Command Language?
- XML Namespaces
- Implications re underlying “Transport” systems
- ….

XML for Data Exchange in OPC

- Platform independence //compare with COM
- Merits relative to HTML
  - XML Parser simpler.
  - Result more reliable.
- How far down…?
  - Directly from IO Device?
  - Where does "WML" fit in?
- Is verbosity a real issue?
  - Negligible effect on transmission time over Ethernet
  - Parsing time?
  - Depends on presetting context and maintaining state
- In what response-time granularity?
- What impact on determinism?
- ….

XML for Schema Description in OPC

- Merits relative to MIDL, IDL, etc.
  - W3C specification builds upon prior lessons learned
  - Will be used much more...
  - Translation into implementation much easier
  - Translation into implementation much higher quality
  - Platform independence. Implementation independence.
- Which version?
  - Schemas-microsoft-com?
  - Or W3C XML-Schema
- Adoption in ISO/IEC standards work.
  - Example: IO Device Profiles
- ....

XML Namespaces in OPC

- URI structure well defined for expansion
- Distinction between location (URL) and namespace (URN)
- Inpacts electronic access to published schema
  - Isolates and allows late binding of URN⇔URL.
  - Can limit / control access to a part of the schema
- More frequent updates/improvements feasible
- More reconfigurability
- ….

Implications re underlying transport services

- Allows OPC options other than DCOM
- HTTP 1.1 is the baseline for OPC-XML work
  - Examples
  - Working implementations
  - HTTP now decoupled from TCP
- OPC-XML WG members also exploring others:
  - Sockets on TCP/IP
  - UDP
  - MSMQ
  - ...
- Future?
  - HTTP-NG?
  - WAP?

Direction of OPC-DA3 WG

- Expected to be in XML
- Strong data typing
- “Complex data” (Whatever DA2 did not cover!)
  - Structures
  - Objects?
- Commands
  - Example: Upload|Download programs
  - Using XML, standard way to invoke command, e.g., FTP
  - Standard method of discovery
  - Consider XML in future to describe commands/programs.
- IO

Actions suggested to RIA

- Review emerging OPC XML-related work
  - http://www.opcfoundation.org/
- Feedback.
- Influence.
- Adopt

End users need common interfaces
to all types of programmable devices.

Near-Term Objectives Workshop

Section Eight

Open Architecture Controllers Extensibility Issues

Presented by:

David Gravel
Sr. Technical Specialist
Ford Motor Company
AMTD

Open Architecture Controllers Extensibility Issues

David Gravel
Ford Advanced Manufacturing – Sr. Technical Specialist
dgravel@ford.com

Business Drivers for Information Exchange

- Competitive advantage requires knowledge, speed, and agility.
- Currently there is **no uniform practice** for information retrieval to/from robot controllers.
- Need to manage huge amounts of information ranging from I/O status to the reporting for CEO's.
- In order to manage information, we must have a way to measure.

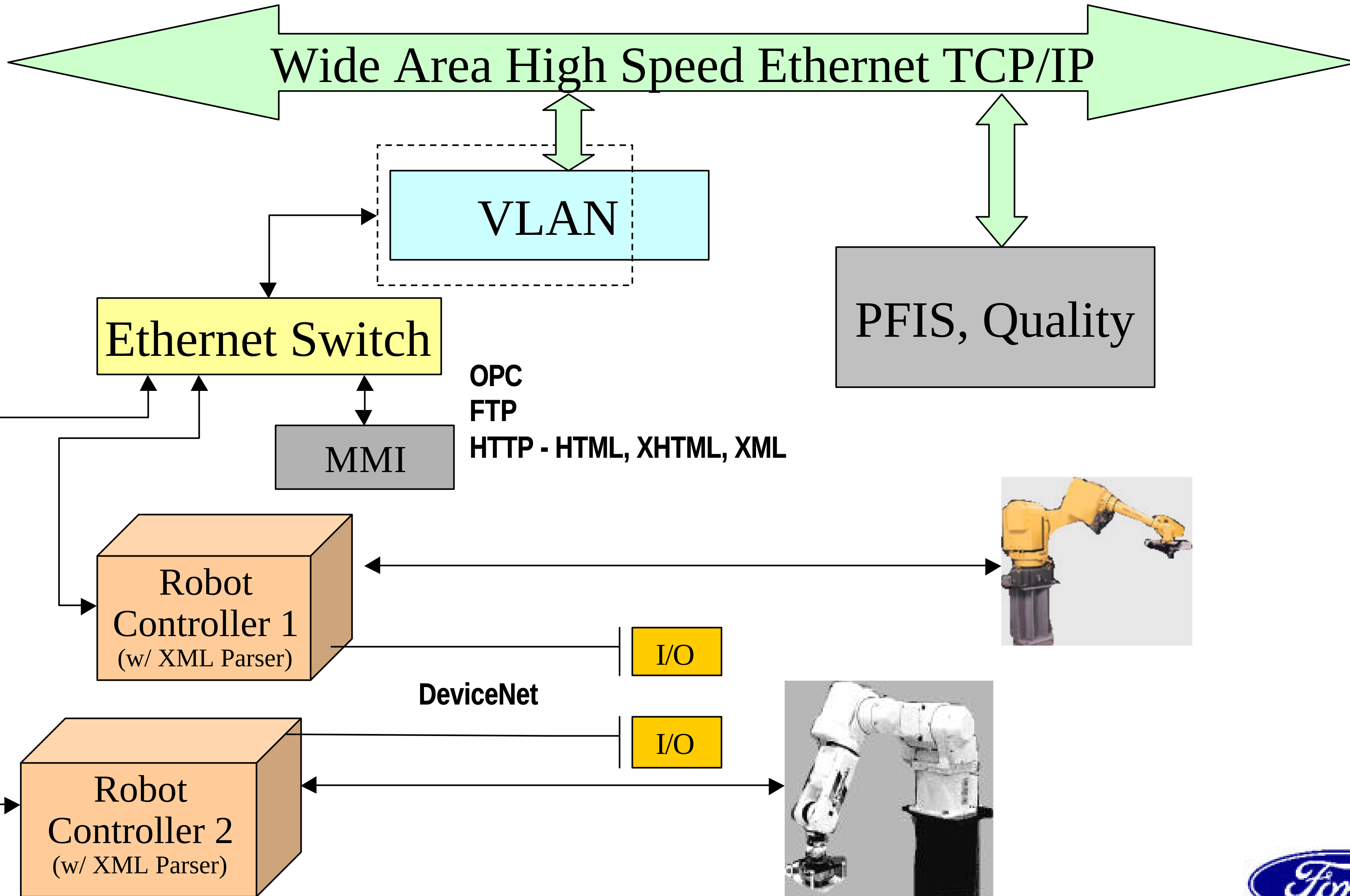
Controller Extensibility

- What extensibility? The industry currently lacks standards and a clear vision of how to achieve this goal.
- Why do we need extensible robot controllers
  - Enhance the process control capabilities of robots by improving plant systems and users access to the robot system, e-commerce enabler, plant scheduling, off-line programming
  - Share data across heterogeneous system
  - Interoperability between different systems
  - Plant custom data applications difficult with HTML

How do we get there?

- Move to use of the high speed Ethernet.
- Use of Ethernet switches to enable collision free communication.
- VLAN technology for network segmentation and security, to produce near real time performance.
- XML for portable data transfer and to provide an extensible custom content for applications.
- Use of Java to parse and process XML data.
- Create robot controllers, (proprietary and non-proprietary) that support the HS Ethernet, XML, and Java.

A Network Topology



Sharing of Data

- A wide variety of heterogeneous systems exist in automotive plants.
  - Proprietary robot system vs. non-proprietary with a mix of operating systems, hardware, and software must all be able to share data for:
    - Remote Diagnostics
    - Real Time Status
    - Process Control Info
    - Remote Software Upgrades
    - Online Help
    - Backups
    - MIS Updates
    - Quality System Monitors
    - On-line Schematics
    - Security Data Monitoring

XML and Interoperability

- Information is accessible and reusable, because the flexibility of XML can be used by any platform with XML software instead of being restricted to specific manufacturers as has become the case with HTML.
- Information content is richer and easier to use.
- Hypertext linking abilities of XML are much greater than those of HTML.
- XML can provide more and better facilities for browser presentation and provide the means for customized user applications.

Issues Surrounding Extensibility

- Proprietary controllers lack of HS Ethernet, XML, and Java compatibility
- Lack of automotive plant HS Ethernet infrastructure
- Training of plant personnel
- Security
- Virus protection
- Remote change of machine state and safety
- Legacy Systems
- High cost of NIC's (getting better)
- Industry Pull

Perspectives from the other Part of the “Big 2” - GM

- Clif Triplett of GM is going to give the GM perspective on plant floor communication infrastructure directions at GM and his vision of regarding extensible controllers.

Near-Term Objectives Workshop

Section Nine

Controller Extensibility

Presented by:

Clifton Triplett
Information Officer
Global Produce Product Process
General Motors Corporation

Controller Extensibility

Information Systems & Services
Produce Product

June 28, 2000

Clif Triplett
Global Produce Product Process Information Officer

Problem Statement

We are challenged to:

- Dramatically reduce the non-value added cost of technical integration *and* the total lifecycle service.
- Realize the benefits of volume price curves seen in the PC industry for replaceable components
- Realize the benefits of service levels seen in the IT industry for mission critical systems

Problem Statement-continued

Today, we must:

- Attack the cost of integration
- Match the availability of technical features with the PC industry
- Select standards, establish a focus and gain momentum

Leverage Market Successes

- Start simple and build on success

- Approach the challenge in waves of standards:

  1. Leverage the Existence and Volumes of Marketplace Technology Standards
  2. Move aggressively on less controversial standards
  3. Evaluate emerging standards for others areas of potential applicability

Where Do We Begin

- Network Protocols (TCP /IP)
- Switched Ethernet (10/100 --> Gigabit)
- Data Representation (XML/XSL)
- Time Services (NTP)
- TCP /IP Address Assignment (DHCP)
- File Transfer (FTP)

Possible Next Areas

- VLANs
- Quality of Service
- SNMP MIB II

Breakout Sessions

The attendees were divided into three groups. Each group was charged with discussing the following requirements:

1. Event correlation, and time services for alerts and alarms
2. Program upload, download, compare, and version control
3. Configuration management, i.e., centrally managed configuration and initialization of all network-programmable devices
4. Reduction of required skills
5. Speed and success of cold starts
6. Uniformity of infrastructure, e.g., single network and common client
7. Real-time status, production monitoring, and diagnostics

The group reports follow.

Breakout Session A

In Group A, we began with a table listing each of the protocols in columns and requirements in rows, and indicated whether the protocol served the requirements. This is shown in the following table:

	NTP	SNMP, MIB-II	TCP/IP	XML	FTP	Switched Ethernet	DHCP
Time correlation, events and alarms	v	v	v	v		v	v
Program upload/download	v	v	v		v	v	v
Version control	v		v		v	v	v
Configuration management	v	v	v		v	v	v
Reduction of required skills	v	v	v	v	v	v	v
Speed/success of cold start			v		v*	v	v
Uniformity of infrastructure	v	v	v	v	v	v	v
Real-time status, diagnostics	v	v	v	v		v	v

* other solutions possible, e.g., BOOTP

The table doesn't show what's missing to fully support a requirement. Here's what's missing:

- Time correlation, events and alarms: fully covered by the above.
- Version control and configuration management are coupled. Configuration management would define the data model and rules, while version control would uses these. Much is missing. Candidates for the missing pieces include Revision Control System (RCS) and Concurrent Versioning System (CVS), and STEP.

- Reduction of required skills, uniformity of infrastructure: everything above helps. Obviously there are many more things that if agreed upon could help.
- Real-time status, production monitoring, and diagnostics: in addition to the items checked above, some content definition needs to be defined and agreed upon.

Additional items:
A common HMI would simplify things for the operator and for setup. Much content definition needs to be defined and agreed upon here. Some notes on the HMI:

- Reduce training costs, allow personnel rotation, realize different policies
- Some different, depending on application
- Standard corporate GUI
- Vendor provides GUI in 90% of cases
- 10% of users take off/don't buy GUI, and add corporate standard or buy one
- GUI <-> controller standard
  - Data model is surprisingly uniform now
  - XML data model would be the standard
  - Style sheets are vendor/user defined
- Security is an issue, authorization is an issue
  - Today's products can be used to achieve security and degrees of authorization

Breakout Session B

Key functions and requirements:

1. Alerts and alarms
   1.1. Event correlation
2. Program upload | download & compare (UDC)
3. Configuration, initialization and configuration management of all devices on the network.
   3.1. Version control
4. Disaster recovery
   4.1. Cold start. (Re)-load system software on device.
   4.2. Speed | success
5. "Real-time" status.
   5.1. Production count
   5.2. Actual cycle time
   5.3. Machine down
      5.3.1. Cause
         5.3.1.1. Fault monitoring
6. Common client
7. Simplify device wiring
   7.1. Uniformity of infrastructure
   7.2. Single network
8. Reduction of skill set required for configuration, startup, operation, and maintenance.
9. Reduction of cost and ease of integration.
   9.1. From "robot on skid" to "cell" to "line"…very expensive and time-consuming process of validation & integration…would like it to be "directly plug & play".

Group discussion notes

1. Caution against direct IT-system access to low-level device (e.g., raw IO) for data, alarms, etc…
2. Need for uniform interface across robotic devices
   2.1. Review MMS/companion for robots for pertinent services needed today (check against current IT applications) and update, using XML.
   2.2. Identify common core + vendor-specific extensions.
      2.2.1. Over time some vendor-specific extension will mature and be folded into the "common core", and some new extension will emerge.
      2.2.2. Issue: Not only a "robot" interface issue. Other devices (e.g., PLC) communicating with it must also support the same "common core".
         2.2.2.1. Consider mappability across schemas of different devices (e.g., PLC, robot). Look at Microsoft "XML-Schema mapper" tools… "func-toid", "scriptlets"….see "BizTalk".
            2.2.2.1.1. Schneider is shipping PLC programming environments with such tools.
3. Can we move to "Wireless networks" to make startup/integration/testing or plant floor rearrangement swifter.
   3.1. Make provision to exploit this technology. Example: Provide "PC Card slots" in controllers. Provide for IEEE 802.11B NICs.` 11MB capacity… Issues: dead spots, noise. IEEE 802.11B supports multiple base stations (alleviates the issue of dead spots).… "Reliable wireless ethernet" techniques/protocols are emerging.
      3.1.1. The wireless technology has potential application on the vehicle being built. (Build specs/options; process build&test history; audit info).
4. The group agrees on the principle of leveraging mainstream solution techniques, solutions, interfacing technologies, rather than "grow your own…" that don't "plug & play".

Breakout Session C

Single network for information systems = ethernet 10/100. 10 Mbps is shared with non-control applications now; 100 Mbps will be dedicated for control in the near future. This should be implemented intelligently, with priority management. Users will specify application traffic and topology.

File upload and download: use TCP/IP, ASCII, and FTP. WEBDAV for versioning status flags. Applications will do the file comparisons. Authentication should be done by destination address for security.

Central configuration management and initialization: IP address assignments should be done using DHCP.

Reduction of required skills: we need fewer networks and simpler networks, fewer tasks to perform, common interfaces, and common presentations.

Uniformity of infrastructure: common client, thin client, XML

- Device profile
- Status, including I/O
- Teach pendant

- Diagnostics
- Alarms and logs
- Process status data

Uniform naming standards

Event Management, alarms and alerts (can be considered part of Uniformity of Infrastructure requirement)
NTP
Producer/consumer model
SNMP is a large standard. The question is how much is needed.
OPC and CIP are candidates.
Other candidates:

- Modbus/TCP
- ProfiNet
- NDDS from RTI
- Homegrown messaging system

Action Items

We discussed the value of "war stories," which are case studies of laboratory or field experience with the data interface and transfer standards that we have been discussing. These studies address the questions:

- What standard did you look at?
- How did you use it? Laboratory testing? Production? Robotics applications? Desktop environment?
- What worked? What didn't?
- What were the benefits?
- What needs to be done?
- How should validation testing be structured? What tests can be made?

Various group members were asked to submit their "war stories" to the email list, openarch@nist.gov. Here are the assignments:

1.	GM (Triplett):	Report on experience with NTP Rollout
2.	Rockwell (Dan Hornbeck):	Report on experience with TCP/IP, UDP
3.	GM (Andrew Hamor):	Report on experience with FTP
4.	RIA (Don Vincent):	Poll members who were not in attendance for their case studies and field experiences
5.	NIST (Fred Proctor):	Draft questionnaire on case studies of field experience
6.	Fanuc (Gary Rutledge):	Report on experience integrating httpd
7.	All:	Submit ideas for ways to collaborate remotely (e.g., conference calls, NetMeeting) to the email list

When collected, these case studies will help the group pick high-value targets for near-term testing. The group then needs to determine validation criteria and devise a test plan. This will take place at the next meeting, tentatively scheduled for a day prior to the RIA Forum in November.